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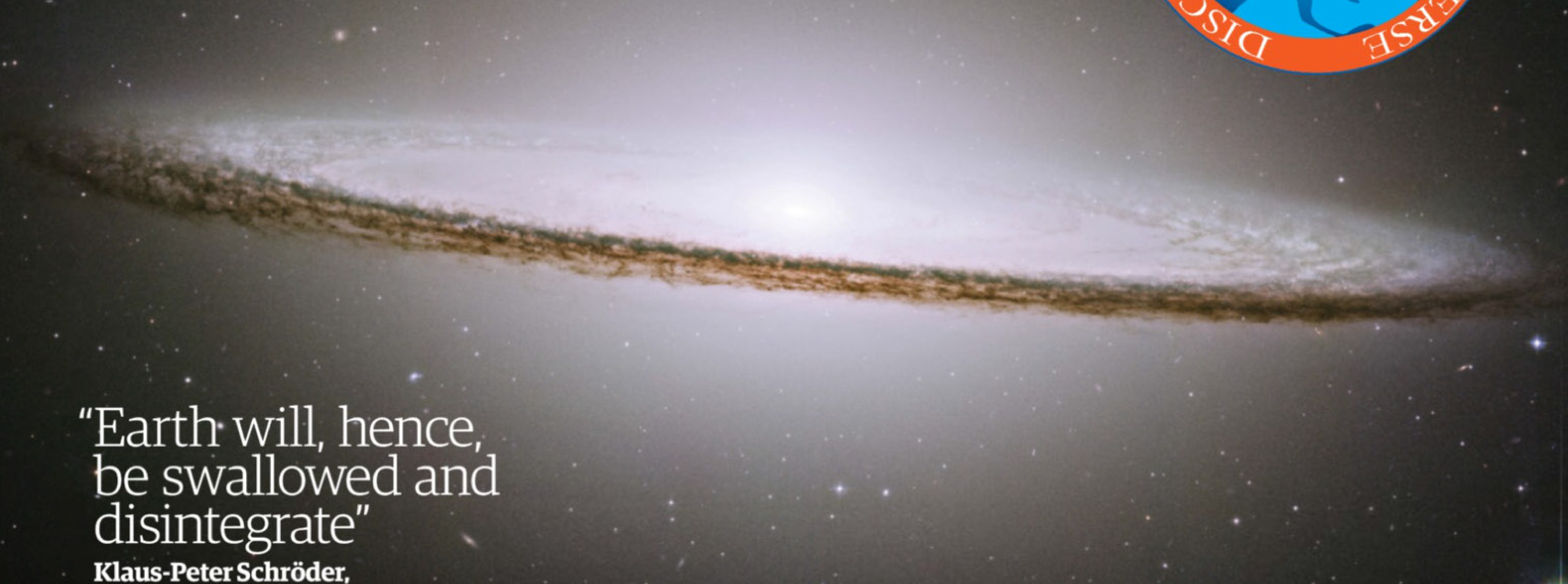


> "Earth will, hence, be swallowed and disintegrate"
>
> **Klaus-Peter Schröder, University Observatory of Hamburg**

When we are presented with the prospect of an end-of-the-world scenario, be that an environmental catastrophe that wipes the human race off the face of the plane, or a cosmic event billions of years from now that consumes the Earth, most of us react with a kind of frank pragmatism: it won't happen to us, because we'll be long gone by then.

This really isn't such an irresponsible attitude to hold, because the events we talk about in our What is the Future of Earth? feature this issue are an inevitable consequence of cosmic evolution. There's not an awful lot that can be done to stop a swelling red giant expanding and torching the surface of our fragile planet – unfortunately that kind of technology is firmly within the realms of science fiction.

However, technologies that enable us to explore, expand and begin to colonise our Solar System are very much the subject of our new feature series Quest to conquer space, which kicks off with ten technologies to take us to Mars and beyond. We're far from being beyond the whim of the fickle sphere the Earth orbits in, but it seems we have the time to take a stepping-stone approach to our ultimate goal of becoming more than just a footnote in the history of our galaxy.

On a lighter note, this issue you'll also find a full guide on astrophotography in the Stargazer section (page 80) this issue. We get loads of photo submissions every month for the Me & My Telescope section of the mag (thank you!), so we thought it was time we gave something back to our readers. You'll find some great advice here, regardless of your experience.

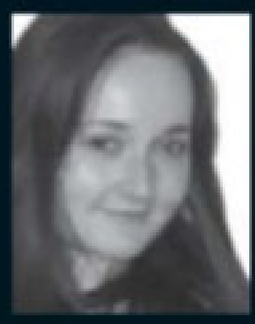
Ben Biggs
Editor

Crew roster

David Crookes

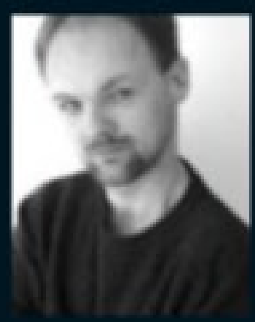
■ This issue Dave has discovered how we can see more planets by blocking out light with a giant space umbrella

Gemma Lavender



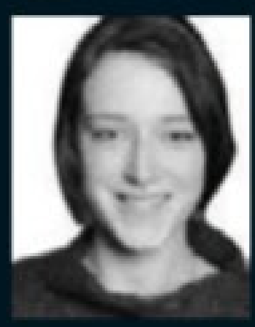
■ Gemma has some disturbing news for those of us still living around ten billion years from now

Luis Villazon



■ So, what's the next step? Luis explores ten cool technologies that will be vital to conquer space

Laura Mears



■ The vast expanse of the Eagle nebula is Laura's oyster in this issue's All About feature

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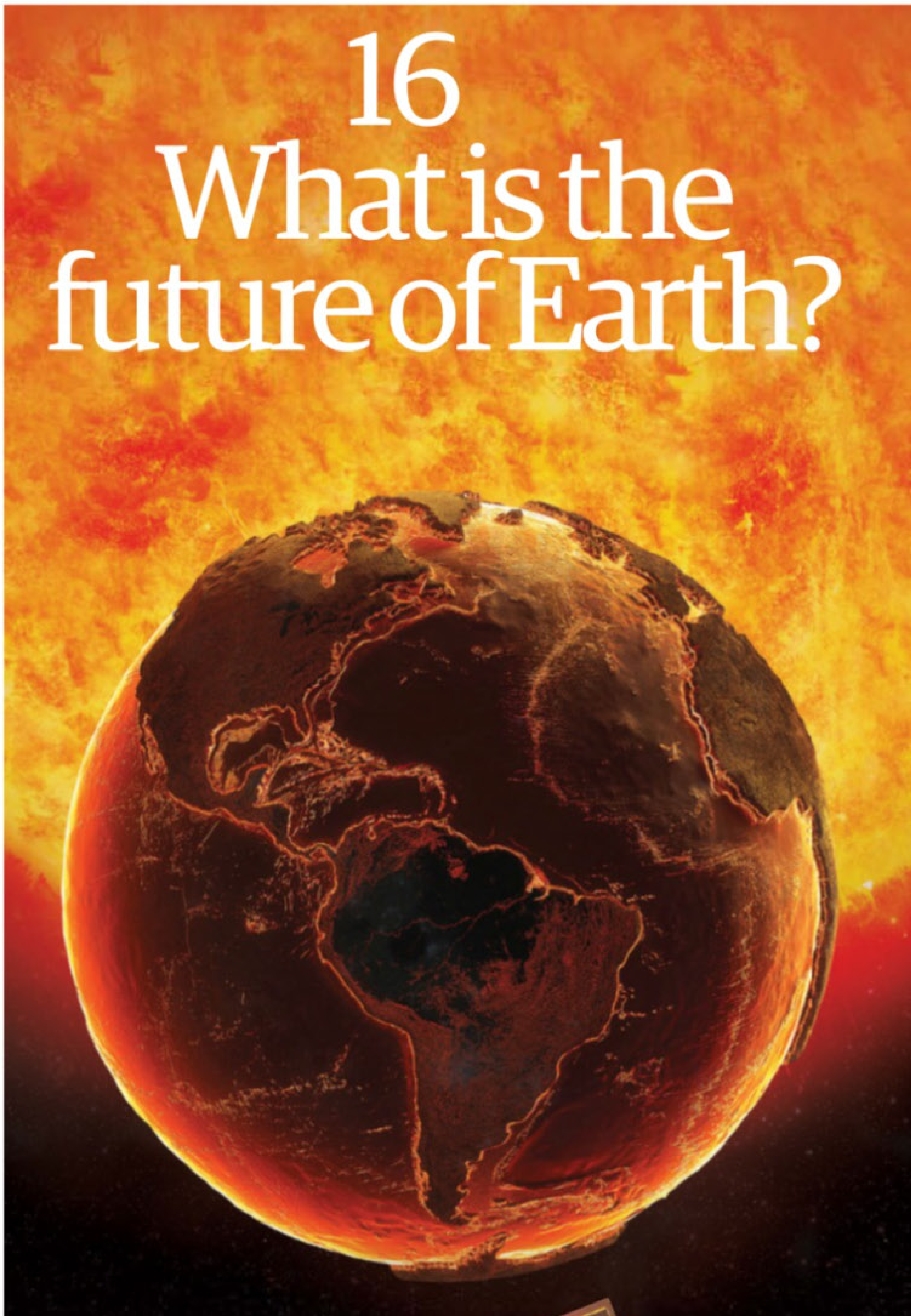
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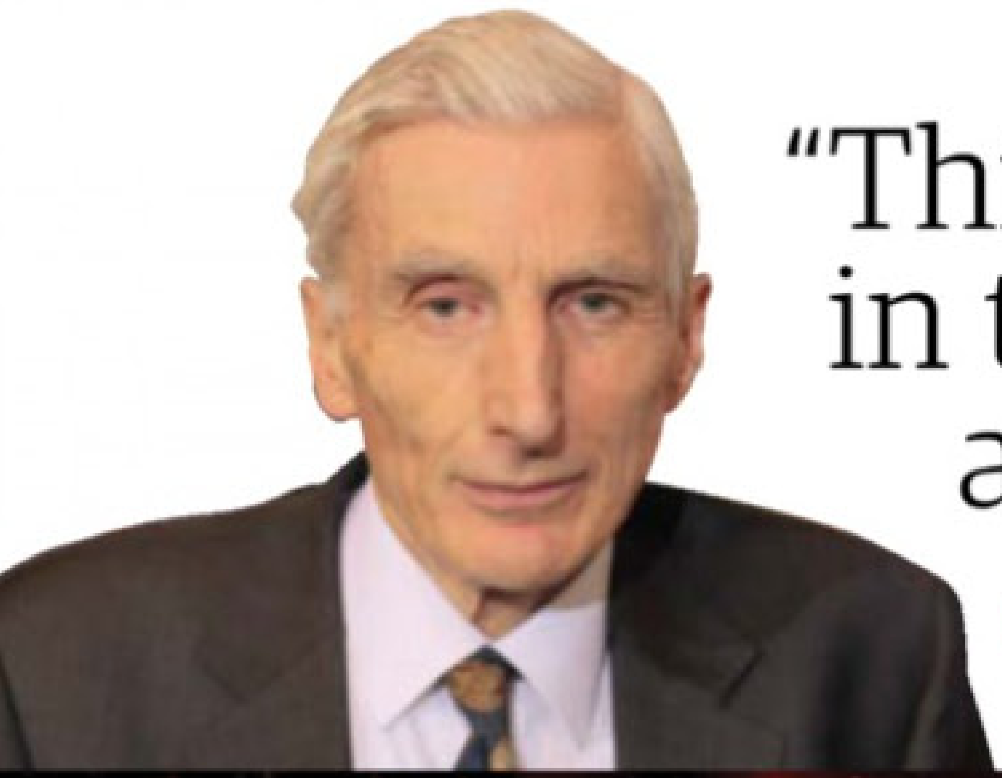

"This takes us back to what happens in the first trillionth of a trillionth of a trillionth of a second"

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LAUNCH PAD

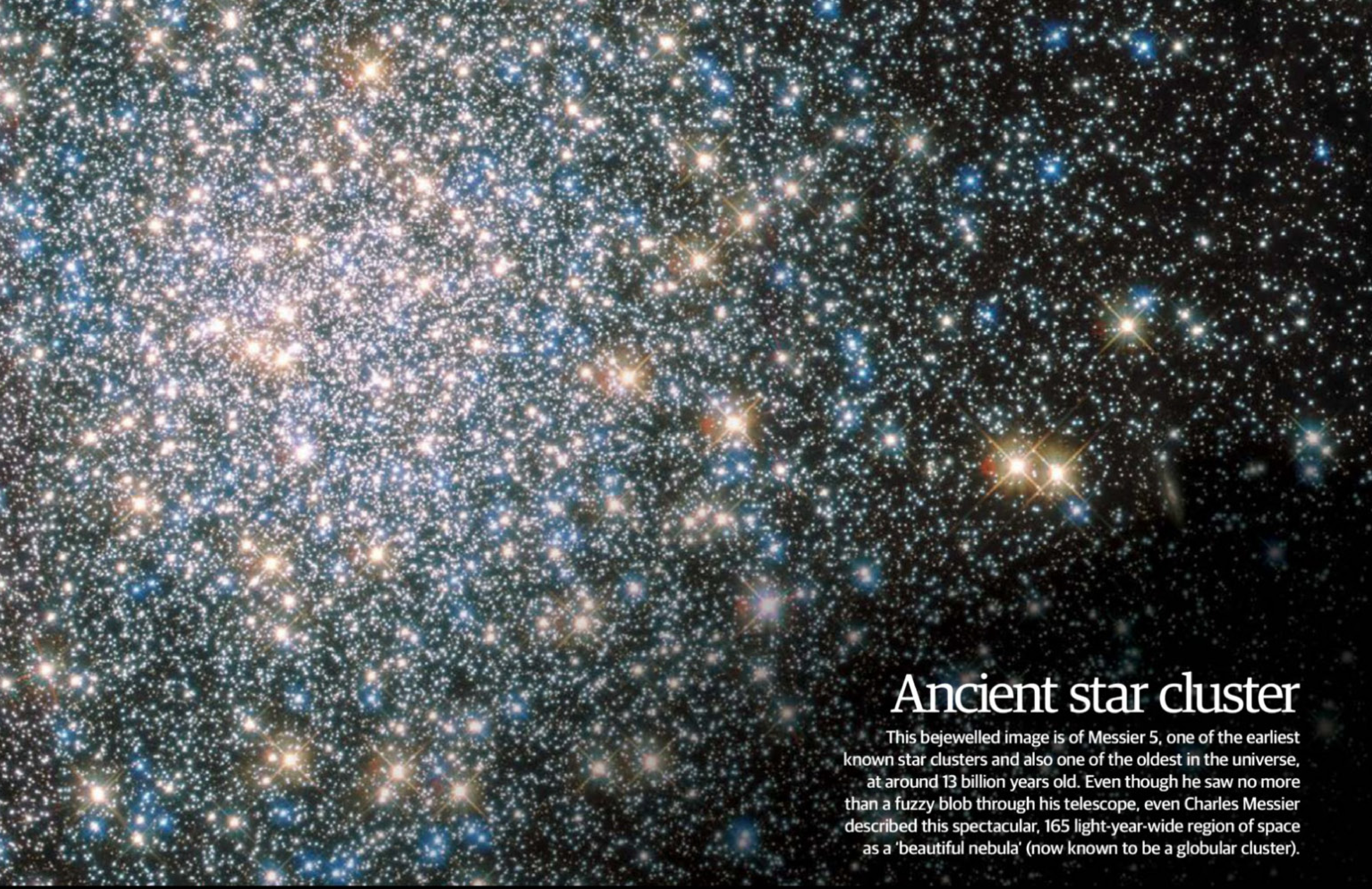
YOUR FIRST CONTACT WITH THE UNIVERSE

Galactic cannibal

The small and neat spiral galaxy on the right-hand side of this image is NGC 1317, which has had a relatively sheltered and uneventful lifespan so far. This is all about to change in its near future, when the giant galaxy in the centre, NGC 1316, bowls straight into it. This lenticular monster already shows evidence of having consumed a dust-rich spiral galaxy around 3 billion years ago. It's evidenced by unusual dust lanes and tidal tails from stars that have been torn from their original positions and thrown into intergalactic space. The galaxies are around 60 million light years away in the southern constellation Fornax.

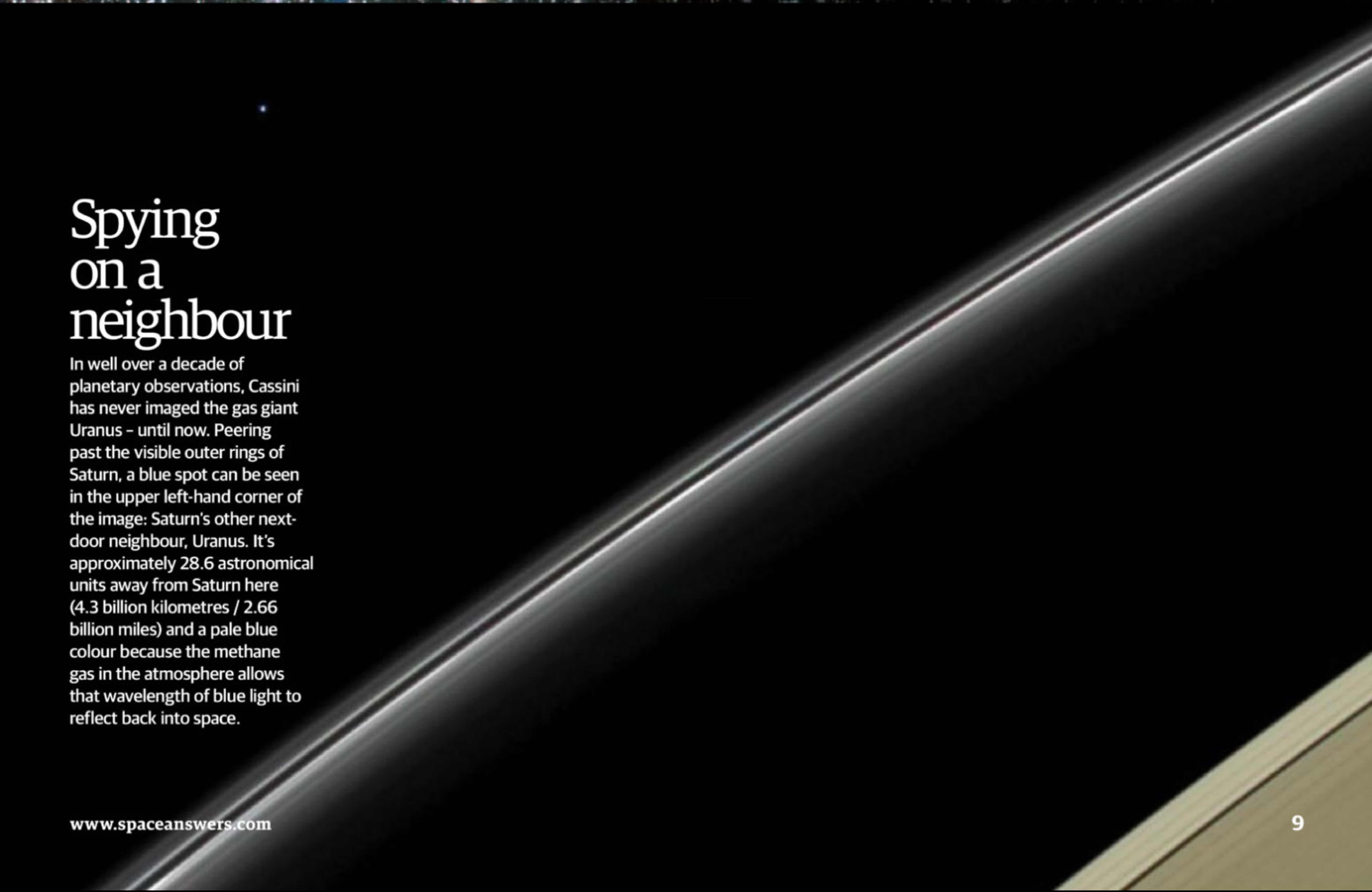
Robonaut 2 gets his space legs

For the only crew member of the ISS entitled to be completely legless for its entire tenure aboard the Space Station, Robonaut 2 seems remarkably pleased to receive its new limbs. Delivered by the SpaceX-3 commercial cargo flight, R2's legs will give the robot the mobility it needs to help the crew out with routine and repetitive tasks, both inside and outside the ISS. This will free the crew up for vital tasks and scientific work.



Ancient star cluster

This bejewelled image is of Messier 5, one of the earliest known star clusters and also one of the oldest in the universe, at around 13 billion years old. Even though he saw no more than a fuzzy blob through his telescope, even Charles Messier described this spectacular, 165 light-year-wide region of space as a 'beautiful nebula' (now known to be a globular cluster).



Spying on a neighbour

In well over a decade of planetary observations, Cassini has never imaged the gas giant Uranus – until now. Peering past the visible outer rings of Saturn, a blue spot can be seen in the upper left-hand corner of the image: Saturn's other next-door neighbour, Uranus. It's approximately 28.6 astronomical units away from Saturn here (4.3 billion kilometres / 2.66 billion miles) and a pale blue colour because the methane gas in the atmosphere allows that wavelength of blue light to reflect back into space.

Soyuz sunrise

This is the track that leads to the launch pad at the Baikonur Cosmodrome in Kazakhstan. It's the route the Soyuz TMA-12M spacecraft took on the evening after this stunning photo was taken, on its way to become the 39th expedition to the International Space Station. Launched on 25 March, 2014, it took one American and two Russian astronauts up into space for a six-month stint aboard the ISS.

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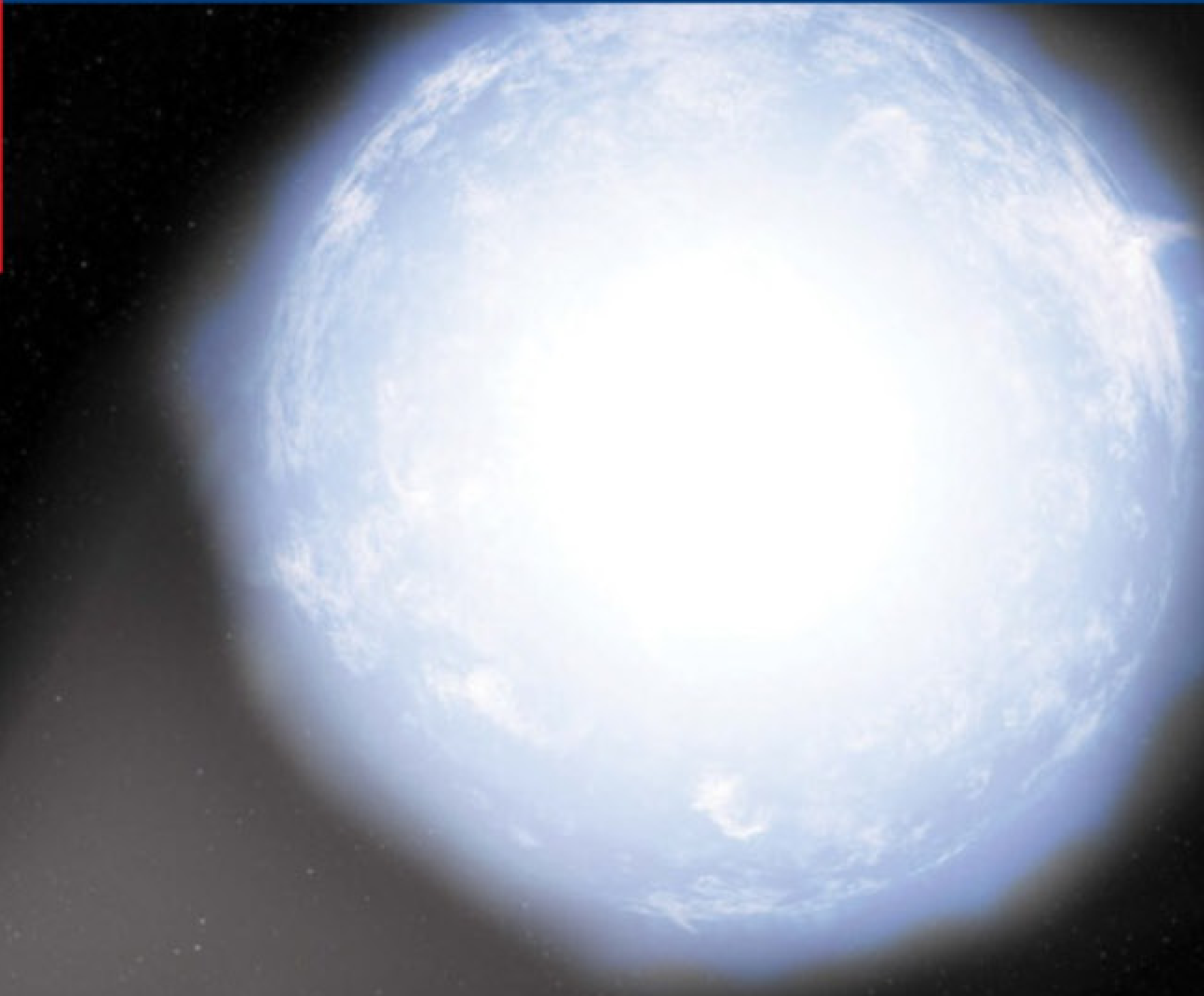

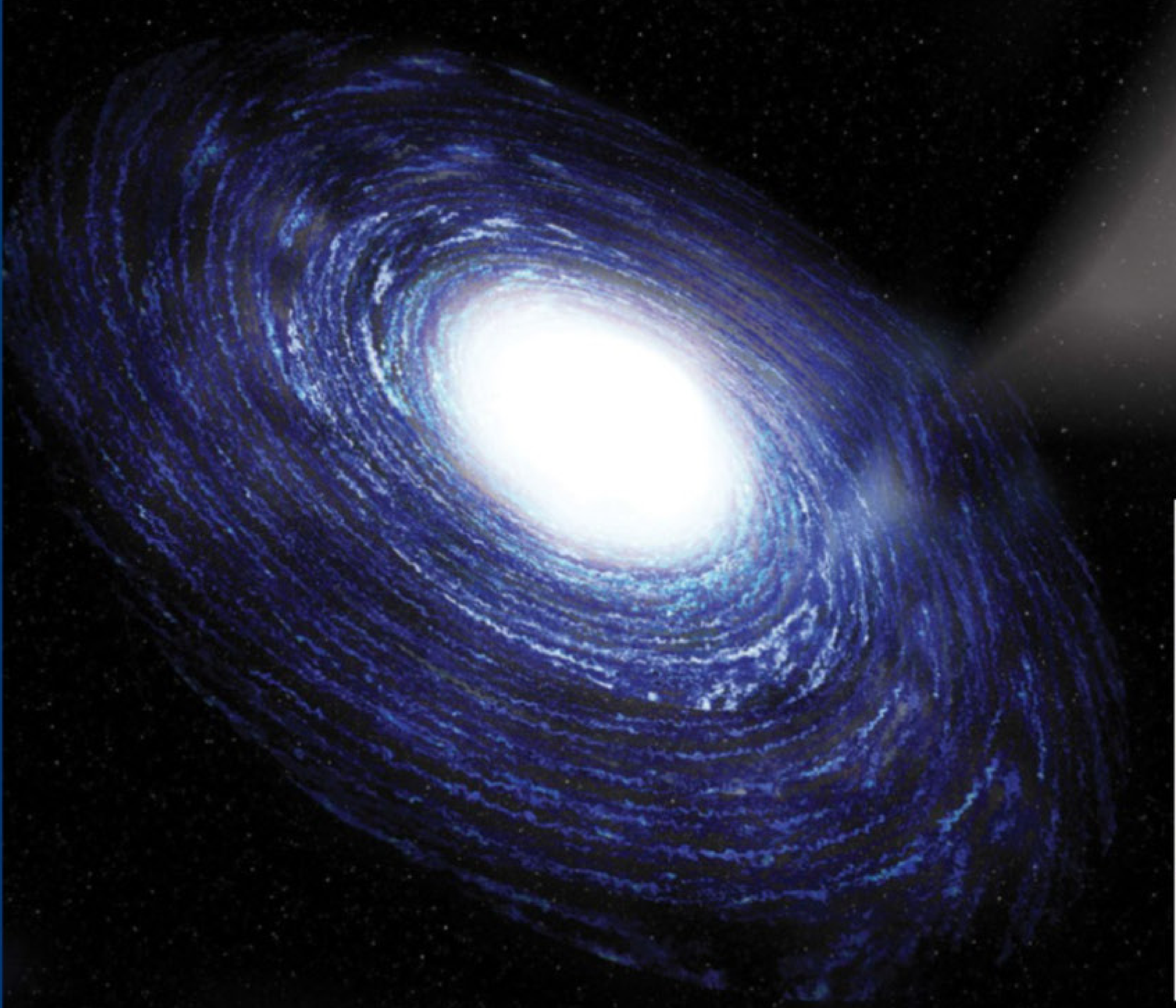

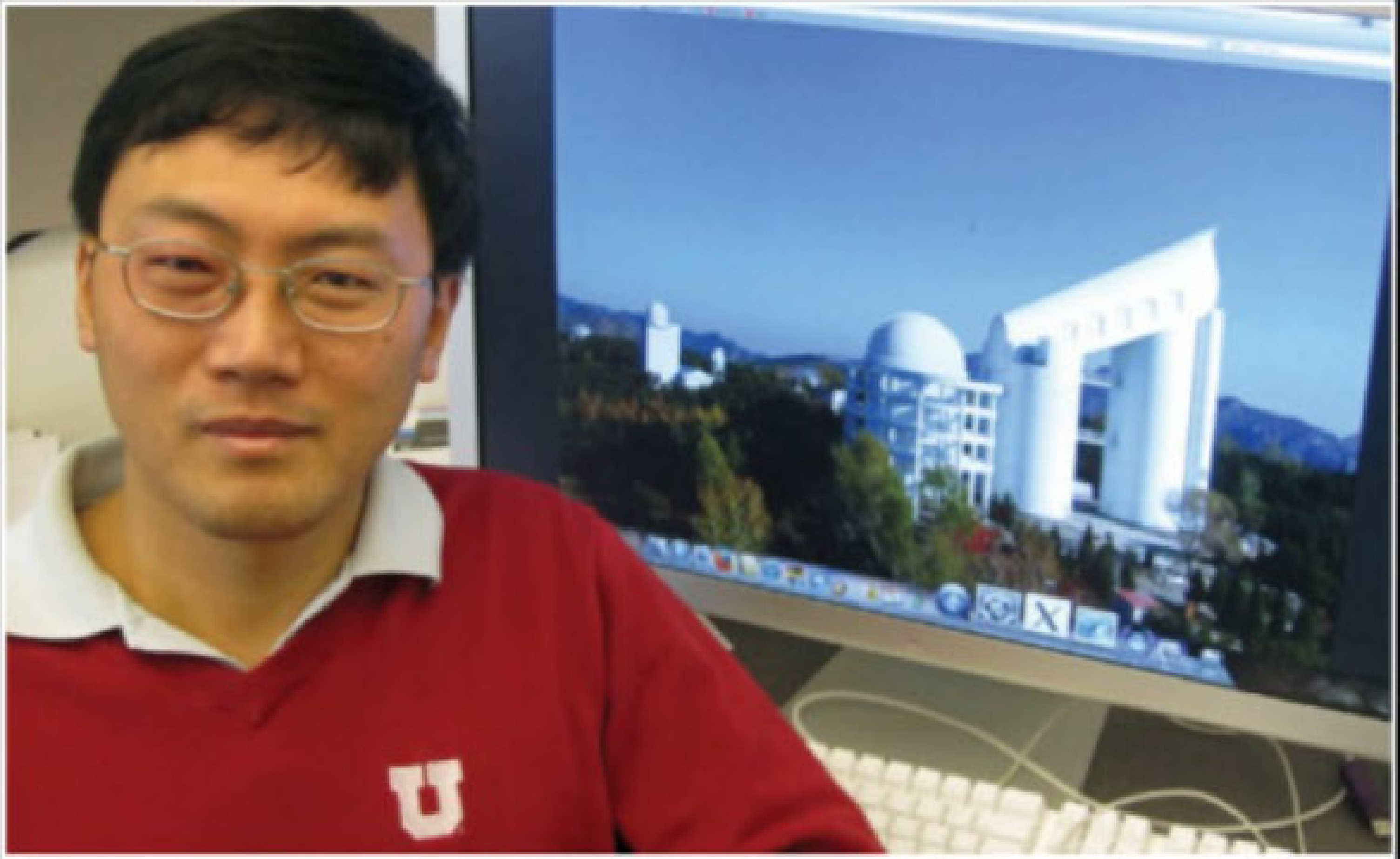

Lead researcher Zheng Zheng (inset) of the University of Utah, found the nearest hypervelocity stars discovered so far using the LAMOST device near Beijing

Massive black hole spits out fast star

Chinese astronomers have uncovered the closest hypervelocity star to the Solar System

Astronomical speed cameras have caught a star racing away from the black hole at the centre of the Milky Way, at 2.3 million kilometres (1.4 million miles) per hour. This star is one of the speed demons of the galaxy and gained its boost from the gravity of a black hole.

Although 42,400 light years from the Solar System, LAMOST-HVS1 (the star's name) is the closest so-called hypervelocity star to the Solar System, of around 20 found so far. Once upon a time they each existed within a binary star system that got too close to the supermassive black hole lurking at the heart of the Milky Way. These binary stars are pulled away from each other, with one being captured by the black hole and the other gaining a gravitational energy boost that flings it away at high velocity.

The star was found by Chinese astronomers using the Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST), which has given its name to the star. The telescope is located at Xinglong Observing Station, north-east of Beijing. With an array of 4,000 optical fibres the telescope is able to capture the spectra of 4,000 stars simultaneously, which can reveal information on a star's size, temperature and velocity.

LAMOST-HVS1 is moving around three times faster than the other stars around it. "If you're looking at a herd of cows and one starts going 60 miles [97 kilometres] per hour, that's telling you something important," says Ben Bromley of the University of Utah. "You may not know at first what that is. But for hypervelocity stars, one of the mysteries is where they come from... the massive black hole in our galaxy is implicated."

The location of LAMOST-HSV1 is among a group of other hypervelocity stars 62,000 light years from the galaxy's centre. According to Zheng Zheng of the University of Utah, who led the study, the star "is the nearest, second-brightest and one of the three most massive hypervelocity stars discovered so far". It has nine times the mass of our Sun and is very bright, with a luminosity 3,400 times brighter than the Sun. It's only the sheer distance LAMOST-HSV1 lies from us that means it appears quite faint to observers on Earth.

Along with a group of other astronomers around the world, Zheng will continue to study the speedy LAMOST-HSV1 and other stars like it. What's particularly interesting about these stars is that they're heading at high speed into the Milky Way's halo, which is filled with mysterious dark matter. How dark matter affects the motion and velocity of these hypervelocity stars could one day tell us something about what the mysterious substance is made of. ●

> "It has nine times the mass of our Sun and is very bright"

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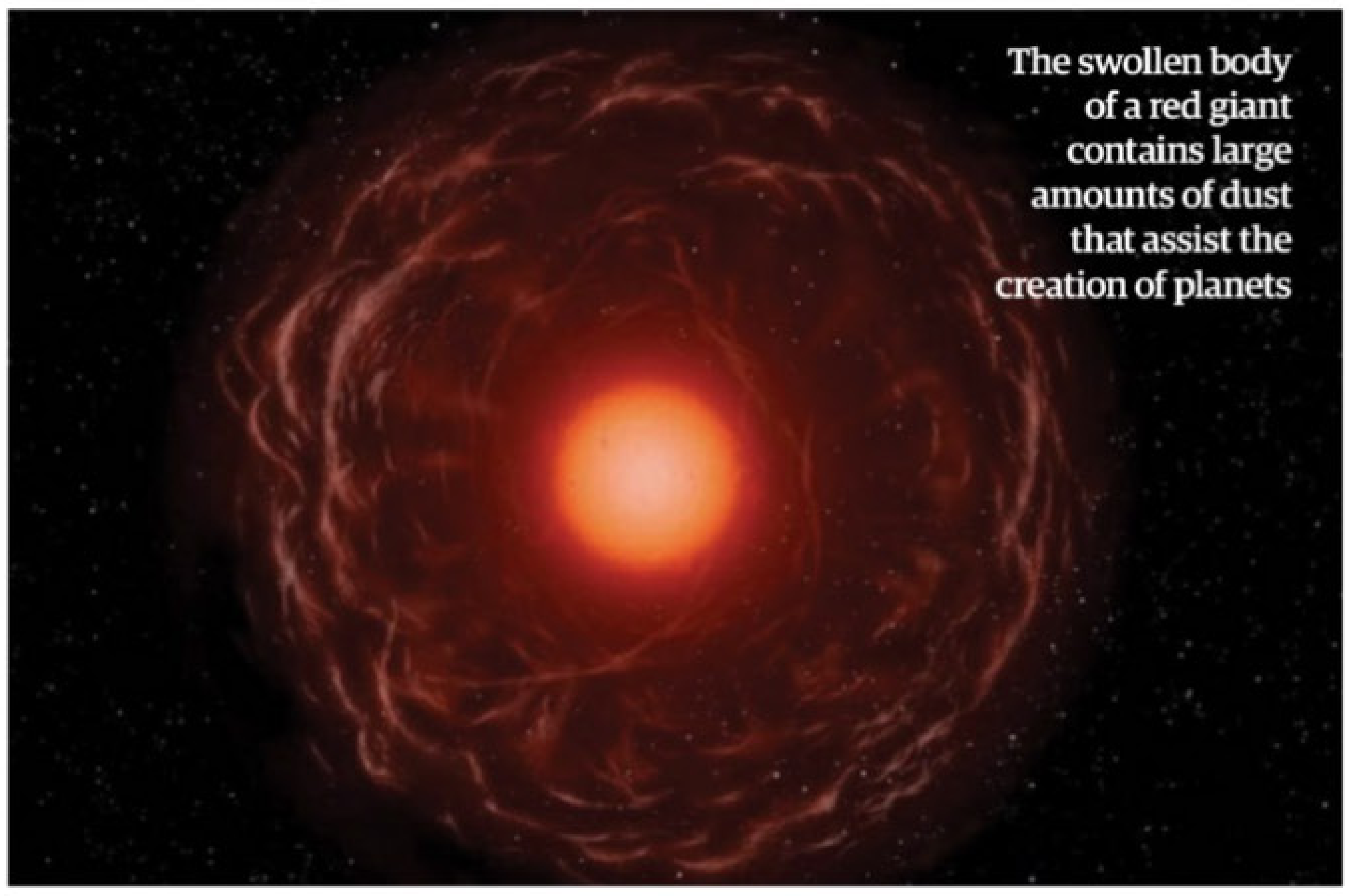
The swollen body of a red giant contains large amounts of dust that assist the creation of planets

NASA makes space dust

Scientists successfully reproduce the atmosphere of a red giant

A team of scientists has re-created just what happens inside the swollen atmosphere of a red giant and their internal processes eventually led to the formation of planet-making dust, right here on Earth. The making of this dust is tipped to help scientists gather clues for understanding the evolution and makeup of the universe.

"The harsh conditions of space are extremely difficult to reproduce in the laboratory and have long hindered efforts to interpret and analyse observations from space," says Farid Salama, the project's leader and a space science researcher at NASA's Ames Research Center. Salama and his team used a specialised facility called the Cosmic Simulation Chamber (COSmIC) to re-create and study laboratory dust.

When a star begins to die, dust grains form around it and are thrown into the interstellar medium, carrying with them the correct elements to form planets after a life cycle that spans millions of years. COSmIC's chamber is able to imitate the conditions that permeate space, where densities are billionths of Earth's atmosphere and temperatures are under -168 degrees Celsius (-270 degrees Fahrenheit).

"We now can, for the first time, truly re-create and visualise in the laboratory the formation of carbon grains in the envelope of stars and learn about the formation, structure and size distribution of stellar dust grains," says Cesar Contreras of the Bay Area Environmental Research Institute and a research fellow at Ames. "This type of new research truly pushes the frontiers of science towards new horizons and illustrates NASA's important contribution to science." ●

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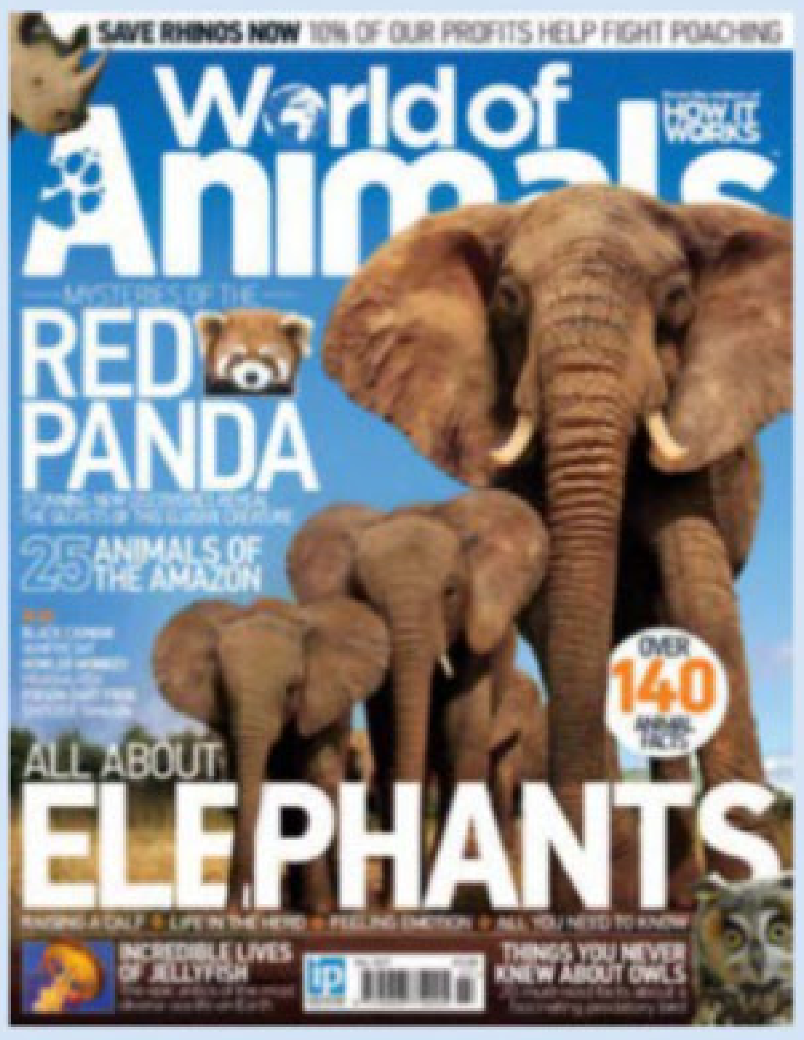
Fight poaching today: Join World of Animals magazine on the Save Rhinos Now campaign trail

World of Animals magazine has teamed up with Ol Pejeta, east Africa's largest black rhino sanctuary, to raise awareness and help prevent the horrific poaching of this endangered species.

Ol Pejeta Conservancy is dedicated to securing habitats for the purpose to protect wildlife. The not-for-profit organisation takes care of over 100 rhinos, hosts breeding programs and has the capacity for many more rhinos that are in need. Starting with issue 7 of **World of Animals**, ten per cent of the magazine's profits will be donated to Ol Pejeta to help one of Africa's most iconic animals survive.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On sale now, issue 7 of **World of Animals** uncovers the mysteries of the red panda, takes you to the Amazon to meet 25 of its unique species and follows the life of the world's largest land mammals, the African elephant.

World of Animals magazine can be found alongside digital editions for iOS and Android, available from **www.greatdigitalmags.com**. Be sure to follow the Save Rhinos Now campaign on Twitter (**@WorldAnimalsMag**) and Facebook, (**www.facebook.com/worldofanimalsmag**). ●

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Magnetic fingerprint of galaxy acquired

ESA's Planck satellite has revealed a new image that traces the magnetic blueprint of the Milky Way galaxy.

The satellite's efforts were compiled from the first all-sky observations of polarised light emanating from the interstellar dust in our galaxy.

Earth not ready for ET contact

A questionnaire sent to 116 American, Italian and Spanish university students has revealed humans aren't ready for contact with extraterrestrial civilisation.

The study comes after the SETI project suggested that we should not only search for other life but also attempt to make contact with it.

First virtual universe created

For the first time astronomers have made a realistic, yet virtual, version of our universe.

Named Illustris, the computer simulation is capable of re-creating 13 billion years of cosmic evolution and includes both normal and dark matter built into the program.

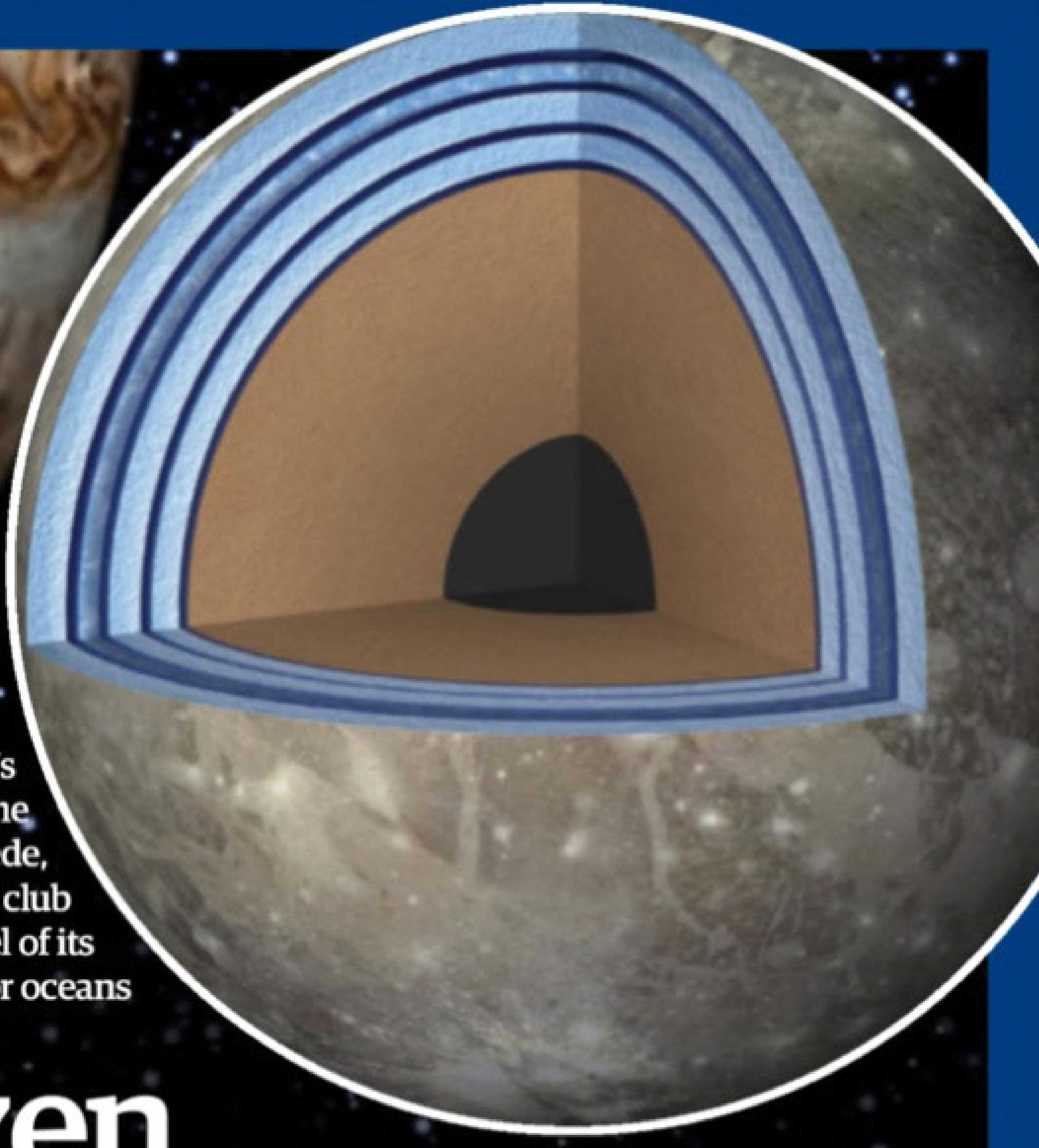
The Widescreen Centre launches app for astronomers

The telescope vendor has released a free app that's brimming with info and deals for every astronomer's needs

The Widescreen Centre, a telescope vendor based in London, is soon to launch a free app supported by the Apple Store and Google Play. It will offer news, special offers and a monthly sky diary, as well as details on upcoming astronomy events.

Developed in-house by the Centre's Simon Bennett and Elena Kostyaeva, the app is shaping up to be very popular with astronomers, with plenty being offered. "As updates to our Facebook and Twitter will update the information on the app, it will provide a real-time resource to our customer base about impending activities and special offers," says The Widescreen Centre's managing director, Simon Bennett. "Anybody with an Apple or Android phone will be able to get live updates." ●

The app can be found for free on the Apple Store, Google Play, Amazon or through the QR code you see pictured here



An artist's concept of the moon Ganymede, illustrating the club sandwich model of its interior oceans

Ganymede: a frozen sandwich of oceans and ice?

Jupiter's largest moon could once have been home to life in its many inner layers

Companion to Jupiter and the largest moon in our Solar system, Ganymede is likely to have stacked its sheets of ice and oceans into several layers.

The moon was thought to possess a deep ocean stuck between layers of ice. However, theoretical evidence suggests that such an organised structure leaves room for the possibility that primitive life could have been found the icy moon. The first layer on top of the rocky core is likely to be awash with saltwater.

"This is good news for Ganymede," says Steve Vance of NASA's Jet Propulsion Laboratory (JPL) in Pasadena. "Its ocean is huge, with enormous pressures, so it was thought that dense ice had to form at the bottom of the ocean..."

While the team feels the moon's ice and water stack is likely, they aren't sure how long the structure will last. "This represents a stable state, but various factors could mean the moon doesn't reach this stable state," says Christophe Sotin, also at JPL. ●

Fossil galaxy could be first that ever formed

Galactic partner could shed new light on how the early universe was composed

Segue 1 differs from other dwarf galaxies, such as I Zwicky 18, as it's no longer in a state of evolution

Segue 1, a dwarf galaxy that's a satellite to the Milky Way and has been under scrutiny by an international team of astronomers, has now been revealed to be an ancient relic left over from the early universe.

The fossil galaxy, whose chemical composition was analysed to unravel its history, is made up of a uniquely ancient composition. Not only that, but the galaxy's star formation wasn't as cyclic as the galaxies we see today, which form and die in a great supernova explosion, before seeding nearby gas with the necessary elements to begin the process again. According to researchers, Segue 1 gave up on its star birth at what would be an early stage of development.

"Our work suggests that Segue 1 is the least chemically evolved galaxy known," says the Carnegie Institution for Science's Josh Simon. "After the initial few supernova explosions, it appears that only a single generation of new stars were formed and then for the last 13 billion years the galaxy has not been creating [any]."

Since the galaxy has been preserved in a state of low iron-abundance, among other heavy elements, and only seven stars in the galaxy are actually in the red giant phase, Segue 1 offers unique information about the conditions in the universe shortly after the Big Bang. ●

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What is the FUTURE of EARTH?

Blistering temperatures, asteroid impacts and a red giant for a Sun – and that's just a small taste of what's in store for our home planet

Written by Gemma Lavender

As the most tranquil planet our Solar System has ever known spins on its axis, seeming to lead us through an infinite amount of days, it's hard to imagine our Earth is going to feel the strain of a variety of events that are set to truly put it through its paces. Yet, as it goes through the motions of its future evolution, the planet we rely on for our survival has a trying time ahead of it. Will our haven grow for the better, or will it become a shadow of its former self as it struggles to counteract the chaos of the universe?

You might take it for granted, but Earth is being tested even at this very moment. Somewhere in the universe there could be a comet or asteroid headed our way. We orbit in a corner of the cosmos containing numerous chunks of rock and ice hurtling through the Solar System, so you'd think that, given the amount of times we've been buzzed by an approaching asteroid that misses us by an astronomical hair's breadth, our days would be numbered. It only takes one behemoth piece of space debris to be at the same place and time as us for disaster to strike, driving a mass extinction across the planet. After all, we know this has happened in the past – just thinking about the fate of the dinosaurs is proof enough.

An asteroid similar to the massive chunk of rock that wiped out the dinosaurs could one day wipe out humanity if we don't find ways to deflect them

Ed Lu, a former astronaut and co-founder of the B612 Foundation, is aiming for the construction of the Sentinel Space Telescope that will alert Earth to potentially dangerous asteroids

> "The only thing so far preventing a catastrophe from a city-killer-sized asteroid has been blind luck"
> **Ed Lu, B612 Foundation**

Around 65 million years ago an asteroid belted our world with such a force that a good portion of life was thrown into disarray as the land shook and great tsunamis took a hold of the world. The 180 kilometre- (112 mile-) wide Chicxulub crater in the Gulf of Mexico, along with bones and fossils of the final resting places of ancient life, marked the beginning of the Earth's Cenozoic Era, a period that continues to this day. Though we've been lucky since, we're always in the potential firing line.

"While most large asteroids with the potential to destroy an entire country or continent have been detected, less than 10,000 of over a million dangerous asteroids with the potential to destroy a major metropolitan area have been found by all existing space or terrestrially operated observatories," says Ed Lu, a former US Shuttle and Soyuz astronaut.

Lu, as part of his organisation the B612 Foundation, aims to build the Sentinel Space Telescope, an Earth-orbiting sentry that would keep a watchful telescopic eye for any potential dangers. Sentinel would raise an early alarm for any dangerous asteroids heading our way. The idea is that finding these threats in advance of them arriving will gift us enough time to deflect anything looking to snuff us out with a single blow. "Because we don't know where or when the next major impact will occur, the only thing so far preventing a catastrophe from a city-killer-sized asteroid has been blind luck," adds Lu.

It's estimated that some 1.4 million years from now we're going to need to thwart comets raining on the inner Solar System from the Oort Cloud, a halo of icy bodies in orbit at the very edge of our celestial neighbourhood. The possible culprit responsible for the future battering Earth could receive is Gliese 710 – a main sequence orange dwarf that will approach the Sun as close as one light year before swinging away again, disrupting the Oort Cloud's structure along the way.

Lu has highlighted an important point with his venture – whether it's asteroids or the uncomfortable proximity of comets, we need to ensure that the likes of the current NEOWISE telescope, as well as the future Sentinel, assist us in keeping our world out of harm's way. However, that's only one hurdle that we have to overcome as thousands of years turn into millions. Provided we can deflect these murderous travellers, we will get a bit of a reprieve from Earth's ultimate fate.

From the surface of the Earth, thousands of years in the future, we will be able to see some significant changes in the night sky. The small red dwarf star astronomers have dubbed Ross 248, which rests in the constellation Andromeda some ten light years away, will move in closer to our Solar System to make it our nearest star ahead of Proxima Centauri, a current 4.24 light years away. It's thought that the pint-sized Ross 248 is likely to reach a minimum distance of roughly three light years from us, in around 33,000 years from now.

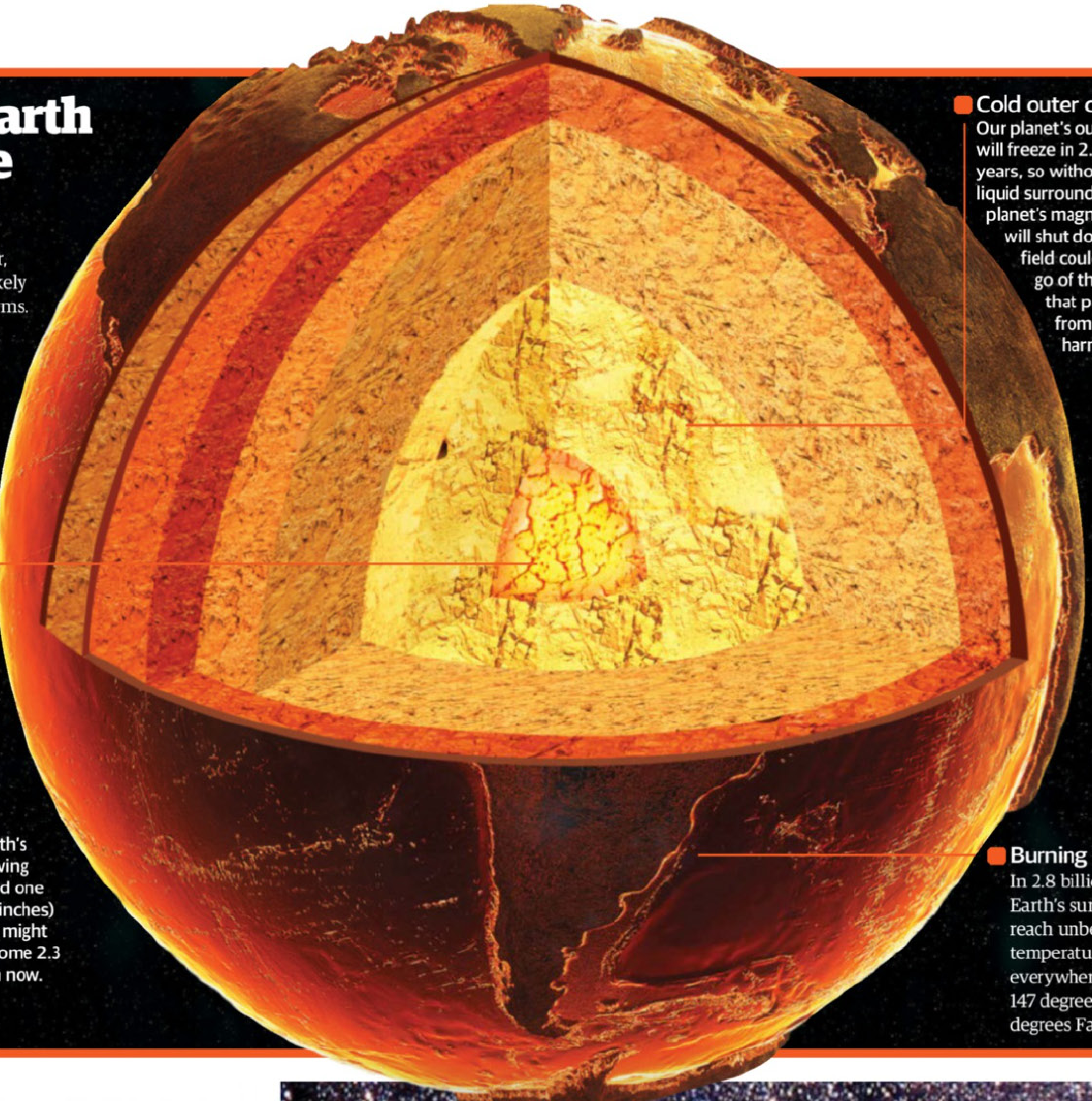
However, it won't be this way forever. Once again the system Alpha Centauri and then Gliese 445 will be made the nearest stars around 8,000 years after Ross 248 has decided to loop away from our planetary system. In fact, the night sky will change over time with several stars taking it in turns to move closer to our Solar System.

If this weren't enough, we can also expect some major activity beneath our very feet. The continents that we live on will be unpicked and sandwich onto others, jostling in such a way that a new supercontinent will be formed 250 million years from now. Some experts call this future landmass Pangaea Proxima, while others have put forward other supercontinent contenders such as Amasia, which would see Asia and North America joining together. Another possibility, Novopangaea, has been predicted by the University of Cambridge's Roy Livermore and would see the closure of the Pacific as Australia docks with eastern Asia and Antarctica moves further north.

The general consensus is that Pangea Proxima, also referred to as Pangaea Ultima, could be the leading setup for the Earth's future landmass. "It's all pretty much fantasy to start with, but it's a fun exercise to think about what might happen," says

The Earth on fire

This hellish Earth of the future will be devoid of water, meaning it will likely support no life forms. While its surface will burn with an unbearable heat, its once fiery core will be frozen solid.



Cold outer core
Our planet's outer core will freeze in 2.3 billion years, so without this liquid surrounding, our planet's magnetic field will shut down. This field could then let go of the ozone that protects us from the Sun's harmful rays.

Frozen core
Currently the Earth's inner core is growing at a rate of around one millimetre (0.04 inches) per year, but this might not be the case some 2.3 billion years from now.

Burning surface
In 2.8 billion years Earth's surface will reach unbearably hot temperatures with everywhere averaging 147 degrees Celsius (297 degrees Fahrenheit).

geologist Christopher Scotese of the University of Texas at Arlington. He's credited for dreaming up the next supercontinent when he examined the past cycles that illustrate their breakup and makeup in the past. "You can only do it if you really have a clear idea of why things happen in the first place," he says.

Scotese's idea isn't a completely new one. This continental clustering is similar to the Pangaea supercontinent, which was surrounded by a single global ocean called Panthalassa around 300 million years ago – even before the dinosaurs inhabited the Earth. Just like this ancient configuration, Pangaea Ultima will see the entirety (or at least, most) of its landmass coalescing with its centre, becoming a partially arid desert subjected to extreme temperatures. The Atlantic Ocean would also narrow to a close, bringing America to Africa and Europe.

Provided that we haven't succumbed to the impact of an asteroid or comet, Earth's appearance will certainly have changed. Great natural landmarks such as Niagara Falls will have eroded away and we'd witness the red hypergiant explosion of VY Canis Majoris, as well as that of fit-to-burst supergiant star Betelgeuse. This latter star will end its life in the jaw-

Some 36,000 years from now Alpha Centauri will not be our closest star. Small red dwarf Ross 248 will move in closer, making it the closest star to us before receding 8,000 years later

The fate of our Solar System

As our Sun goes through the motions of its evolution, what does this mean for the planets in our Solar System?

Now

Our Sun

Currently, our Sun is happily burning hydrogen into helium at its core and giving us the heat and light that assists in the sustainability of life on Earth. Around a billion years from now, our star will be a good ten per cent brighter than it is today

The swollen Sun

In around five billion years from now, the Sun will exhaust the hydrogen fuel at its core and will begin expanding. It will have evolved into what is referred to as a red giant after approximately 10 billion years on the main sequence

A hostile Earth
Whether the Sun will survive the red giant phase is a subject that's continually up for debate. The general consensus is that Earth will be engulfed, but if it survives, then its surface will be inhospitable

Hope at Titan
As the Sun evolves, the habitable zone will be pushed further back in the Solar System. At the red giant phase, the Goldilocks zone will be resting around Saturn, making its moon Titan warm enough for life to survive on its surface

The inner planets' death
Without a doubt, both Mercury and Venus will be engulfed by the giant Sun. They will break up and be vaporised in the intense heat

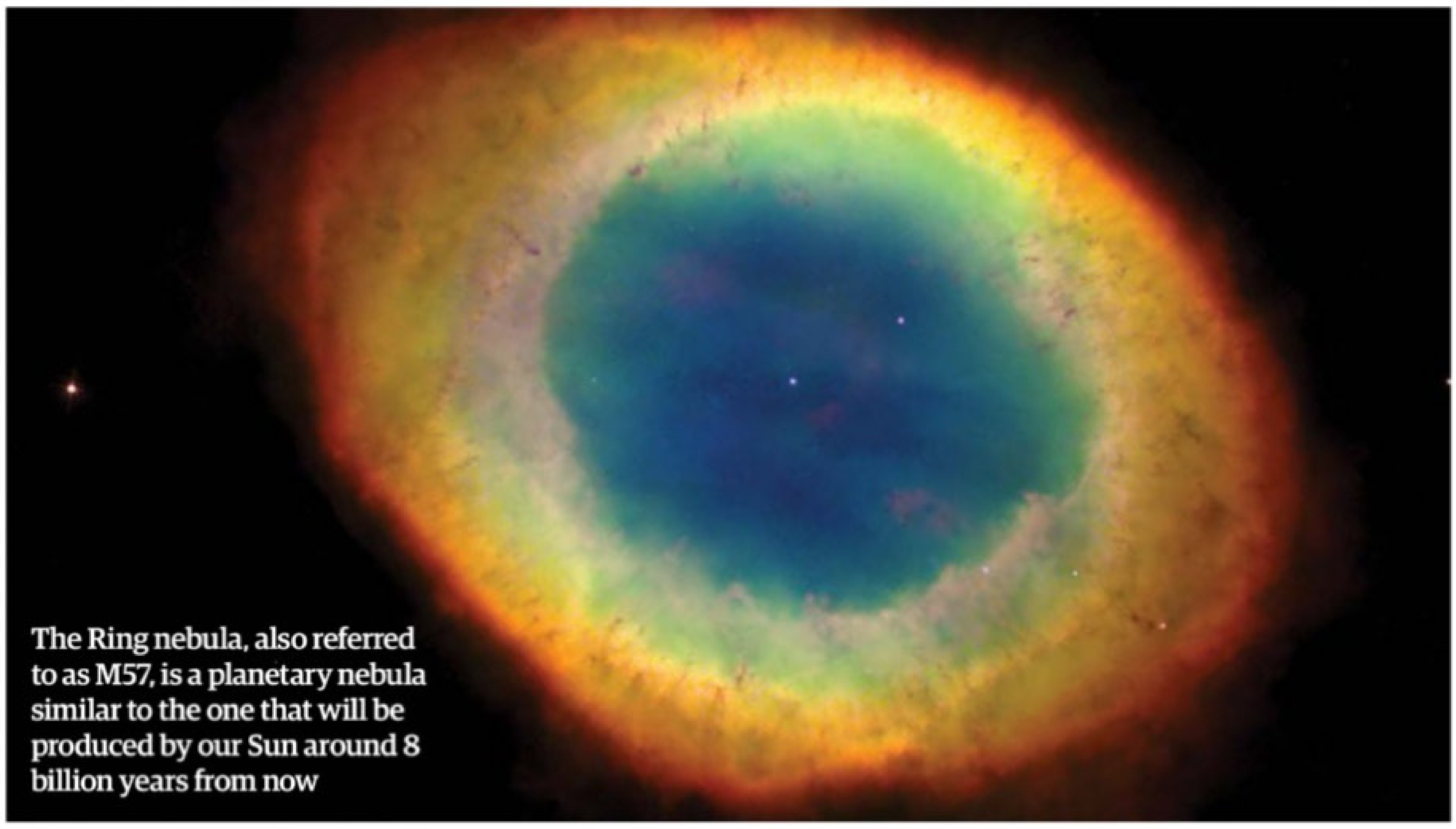
dropping brightness of a supernova tipped to be visible even in daylight. We're at a decent distance to marvel at these explosive wonders, but that's not to say that the show won't come closer to home, bringing with it the ultimate test of Earth's resistance.

When we look at the bigger picture, our planet's fate relies on the mood of the Sun that has, in part, enabled life in the first place. Our star began its life some 4.6 billion years ago, built in a swirling construction yard of dust and gas. This great cloud gathered enough matter in its centre, becoming so hot and dense that fusion of light elements into heavier ones caused the Sun to erupt into existence. The remainder of this disk flattened into an orbiting pancake that would later become the spheres of various rocks, gases and ices that we now recognise as the Sun's planetary companions.

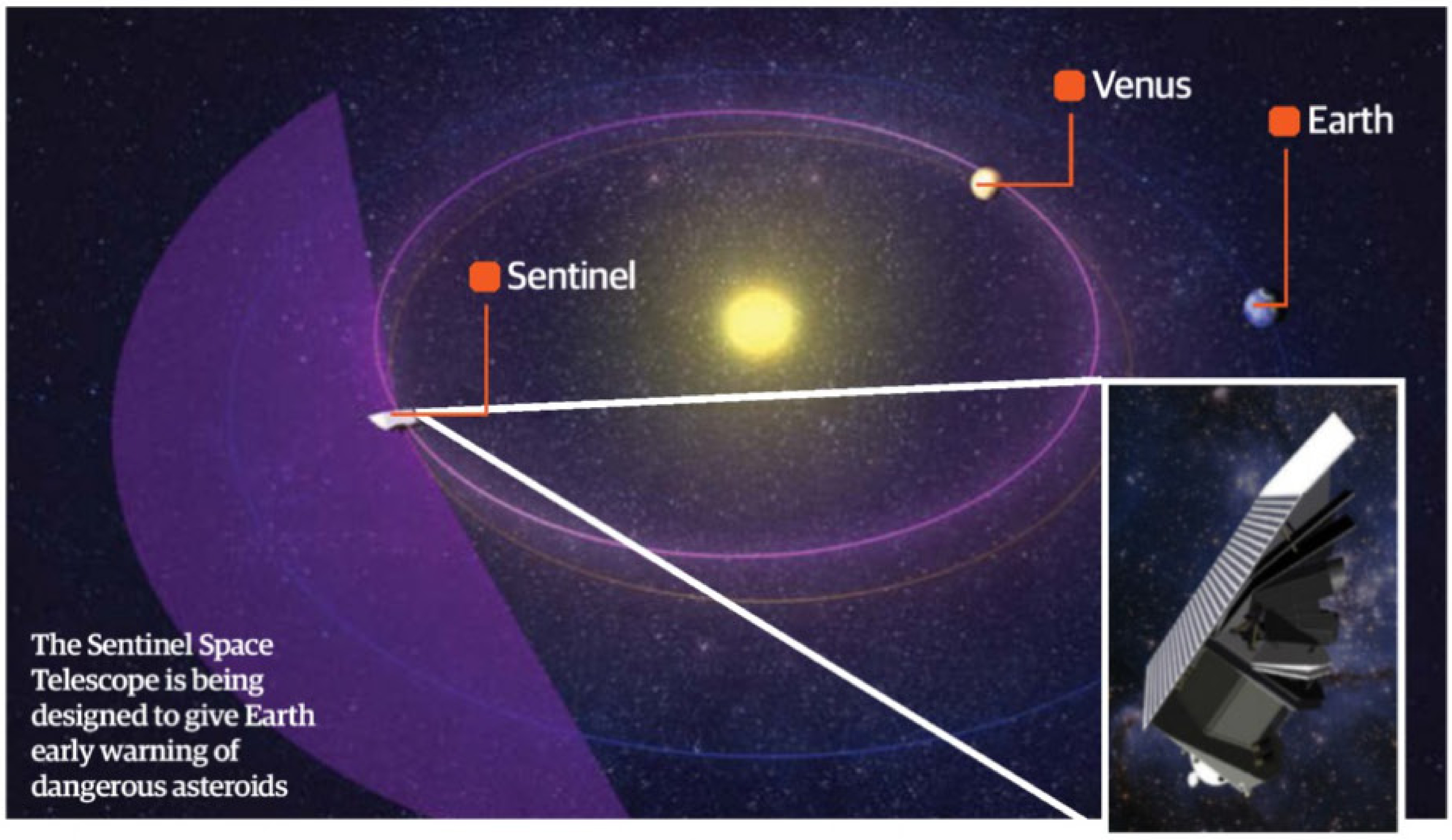
Today the Sun is loosely known as a yellow dwarf - what is more specifically referred to as a G-type, spectral-class star. This essentially means it belongs to the main sequence - a more or less stable section of a star's life. However, another few billion years from now things will start to take a dramatic turn. The inner planets that have been in a stable orbit around our Sun for so long, bravely staying within reach of its violent coronal mass ejections and solar flares, are very likely to feel the brunt of an apocalyptic event. Over this time, the Sun is going to grow up. The hydrogen that it furiously burns into helium at its core will eventually be exhausted and, in response, our star will swell into a red giant - a comparative monster of a star 250 times the volume of our yellow dwarf today.

That's the next chapter of the Sun's life and as the star fills up more of the Solar System, its gargantuan size is likely to see some of its planetary members being written out of its story. The popular consensus is that one of the planets in for the chop is Earth. Klaus-Peter Schröder and his team, currently working at the University Observatory of Hamburg, recently put together a detailed model looking into just how the future of our Solar System will play out. Looking into exact solar models and tidal interactions, the team has reasoned that our Sun will lose a third of its mass as it expands, its rotation rate will slow and it will experience a drop in momentum. Losing this momentum - referred more precisely as angular momentum - would cause a tidal bulge on the star, whose gravity will then pull Earth inwards. With some original speculation that the Earth might somehow survive, the researchers' findings have well and truly blown any hope out of the water.

"Unfortunately, after considering tidal interaction between the giant Sun in its extreme stages with a closely orbiting Earth, we found that angular momentum is consumed sufficiently to reduce the orbit of the Earth enough to lower it into the [red giant's] surface," Schröder explains. "Earth will, hence, be swallowed and disintegrate." Schröder believes that to even think that our planet will survive such an overhaul in its surroundings is nothing more than an "academic comfort", as temperatures soar far beyond boiling point, reaching up to 2,000 degrees Celsius (3,632 degrees Fahrenheit) - equivalent to the temperatures of exoplanets known as hot Jupiters.



The Ring nebula, also referred to as M57, is a planetary nebula similar to the one that will be produced by our Sun around 8 billion years from now



The Sentinel Space Telescope is being designed to give Earth early warning of dangerous asteroids

While researchers think that the Earth will meet a frazzled and devastated end, along with the innermost worlds Mercury and Venus that will be gobbled up by the star's expanding limbs, they have reasoned that for our planet to survive, the entire orbital setup needs to keep a hold of its momentum. Such a feat would also see the outermost planets shuffle in response. "Accordingly, the orbits of all of the planets are going to expand by 50 per cent," says Schröder. "However, that's true only if the momentum is conserved. In that case, the orbit of Earth would exceed the maximum solar giant radius by some 25 per cent."

It's here that some scientists are romancing the idea of an Earth that survives the odds, attempting to find hope that would see humanity beat the rules of the universe. "We could try to steer every asteroid that passes Earth ahead of its orbital movement, then we should gain angular movement to enlarge our orbit well in time," Schröder suggests.

Whether our planet manages to survive or not, it doesn't really matter – at least when it comes to the future of mankind, thinks Schröder. He believes that the Sun has something else in store for us and our star is looking to present us with it much sooner than the latter stages of its evolution. "In about one billion years, long before [the red giant phase] and more gradually, will come the end of the habitability of Earth," he tantalisingly tells us. This is the stage between now and when it uses up all of its hydrogen, before swelling into a red giant. In this respect Earth's future is certainly bright, just not in the way we'd hoped it would be.

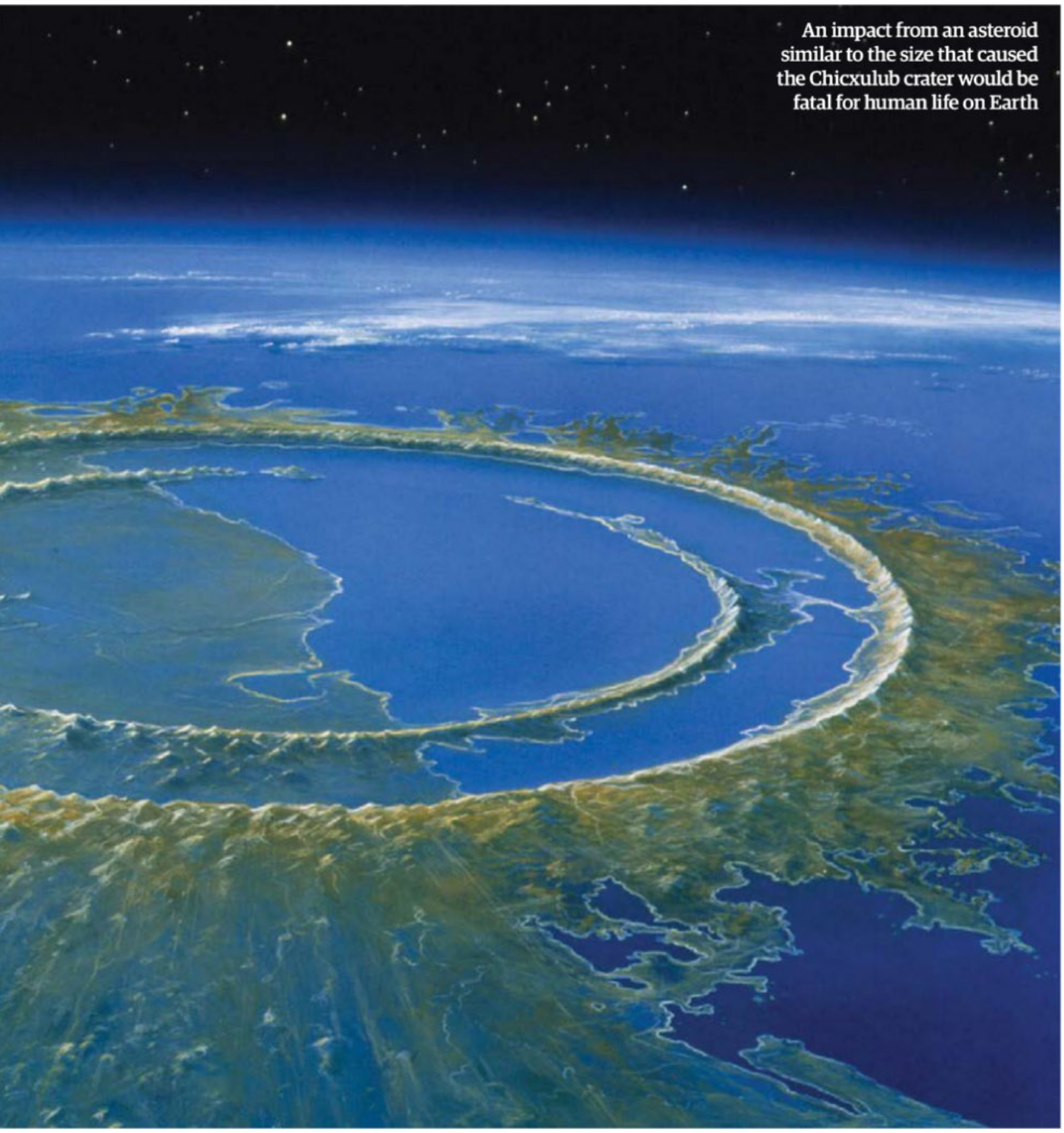
"Earth's future is certainly bright, just not in the way we'd hoped"

You're unlikely to notice it, but the Sun is slowly and ever so slightly picking up in both brightness and size. At the moment, and at a comfortable distance from our star, temperatures are perfect for the existence of liquid water, the region we know as the Goldilocks or Habitable Zone. However, as billions of years pass, what we regard to be a privileged spot in our Solar System will become somewhere that isn't really the place for life as we know it. This is because, for every billion years that pass, our Sun will be kicking up its power output by around ten per cent, in a race to use up the hydrogen that it finds knocking about its core.

With our star turning up the heat, solar warmth mixes with the gases in the Earth's atmosphere, shifting the Habitable Zone backwards through the Solar System and towards the outer giants of the system. "That will be enough to drive the climate into a runaway greenhouse state. That is, when all water boils off and temperatures will exceed 100 degrees Celsius [212 degrees Fahrenheit]," says Schröder.

Clearly Earth's future is shaping up to be a global disaster. With no life able to adapt to the abrupt end of cycles of nutrients and life-supporting gases, there's nothing left to breathe life into its dead surface as even the smallest pockets of water evaporate. Worse still, the brutal treatment dished out by our Sun won't be over even at this point.

It all begins when our planet's interior breathes a death rattle, turning from a molten liquid to a solid that kills off the magnetic field holding the ozone



An impact from an asteroid similar to the size that caused the Chicxulub crater would be fatal for human life on Earth

layer in place. It's this cloak that makes our planet resilient to the harmful ultraviolet rays that our Sun throws at us. Without it, our planet's surface would be treated to a bath of high-energy radiation that has already left Mars with its barren landscape that we are learning more and more about.

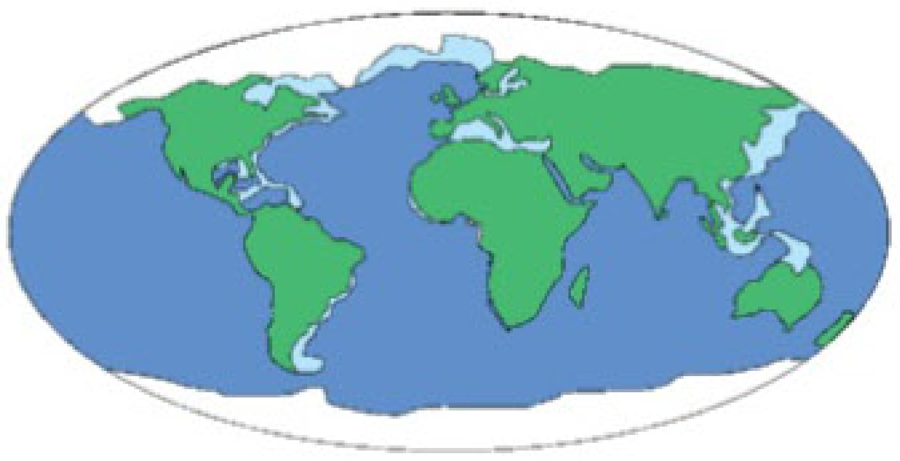
Temperatures will continue to rise for our planet and the gas mark will be well and truly turned up, equating to a rise of more than 140 degrees Celsius (284 Fahrenheit) over the average of around 2.8 billion years from now. Earth will then become host to a climate that bears some similarity to the hellish surface of Venus, long before the red giant phase of the Sun takes hold.

With many experts, including American geoscientist Professor James Kasting, thinking that Earth is heading for higher temperatures and devastation all round, there's a certain urgency to act to escape what would ultimately spell the end of humanity. We know that as the Habitable Zone shifts back, even Mars will get its time in the Sun as our star gets bigger and hotter. The relatively chilly Red Planet will eventually reach a temperature similar to the levels likely to have existed during the Earth's ice age. Further into the future, when Mars is no longer a valid outpost for future colonisation, we will need to look to the gas giants: Jupiter's moon Europa and Saturn beckon. The ringed planet in particular could hold the key to our escape in the form of Titan. "In certain ways, Titan is the most hospitable extraterrestrial world within our Solar System for human colonisation," explains Robert Zubrin, an aerospace engineer advocating the manned exploration of Mars. He has also established the Mars Society, an organisation dedicated to promoting the human exploration and settlement of the Red Planet.

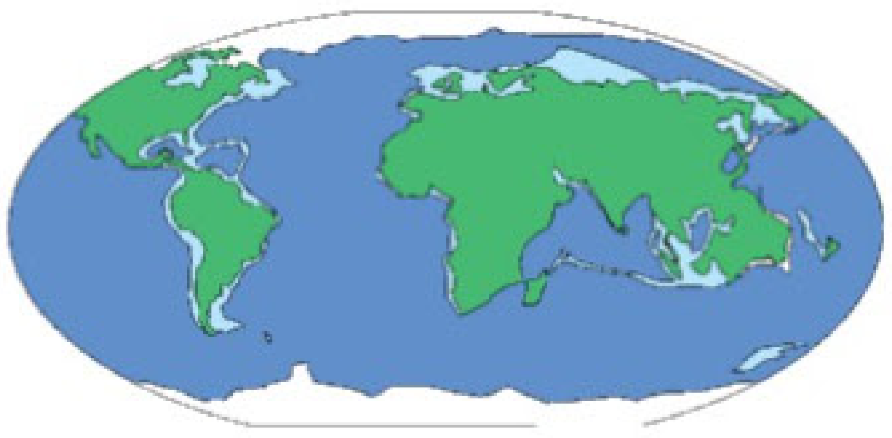
When it comes to Titan's potential, Zubrin refers to its atmospheric mix of nitrogen, methane and ethane with the liquid oceans, lakes and rivers implied by the observations of spacecraft such as Cassini. NASA's famous orbiter also deployed its Huygens lander on Titan to reveal the first and currently only image of an extraterrestrial moon's surface. Combined with a Sun that's continually heating up, this somewhat cooler analogue to Earth could be the answer that the survival of humanity is looking for. However, will we get there before our Sun inevitably expands into us? ●

Our next supercontinent

Today

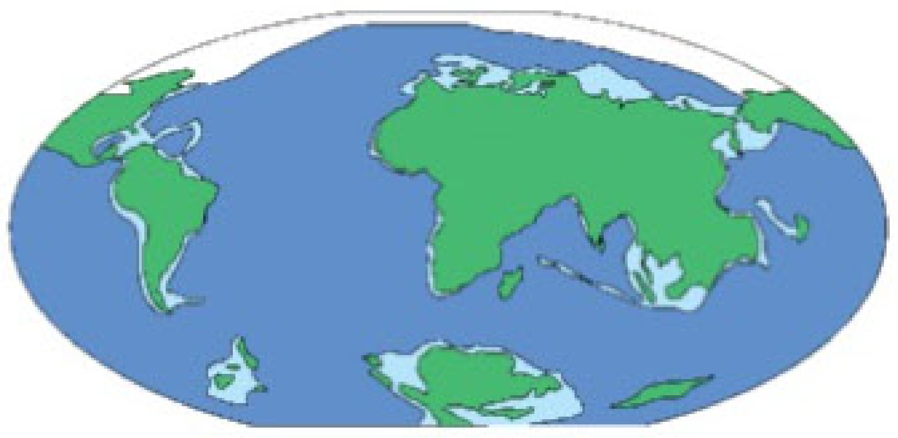


50 million years



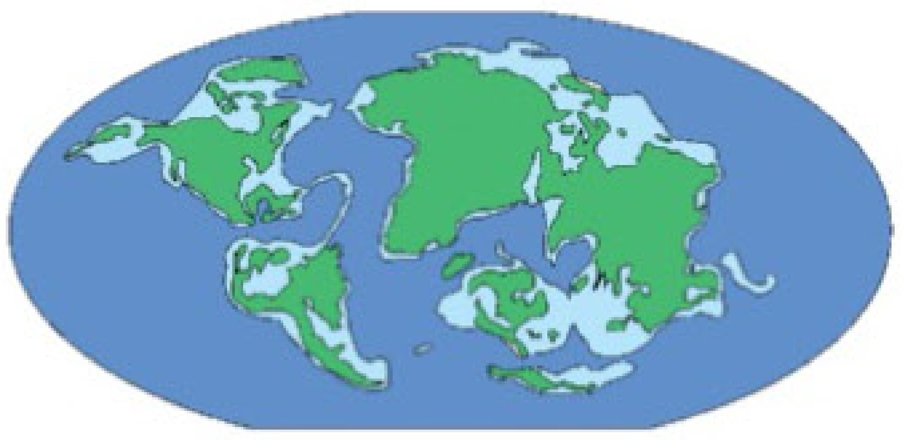
North America will shift to the west, while Eurasia moves east, bringing Great Britain closer to the North Pole and Siberia south. Africa collides with the Middle East and Europe closes the gap of the Mediterranean Sea.

150 million years

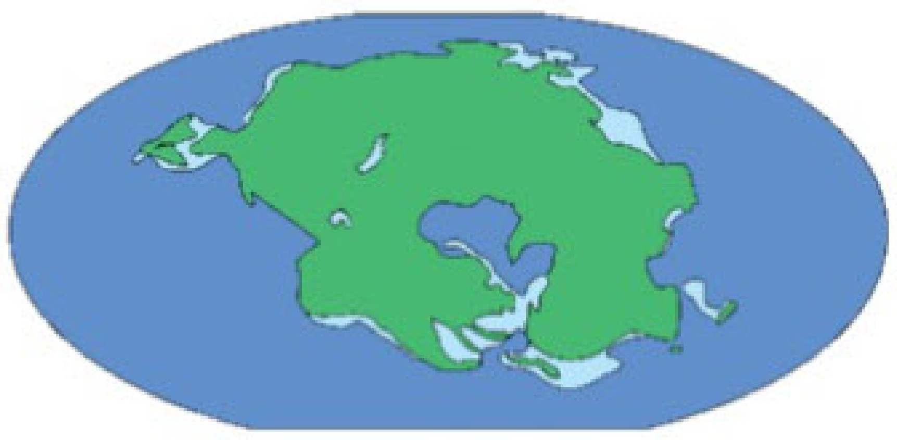


The Atlantic will stop widening and begin to shrink. The Americas could be pushed back in a south-eastern direction and southern Africa could hit the Equator, pushing into the Northern Hemisphere. Antarctica and Australia will join at the South Pole.

200 million years



250 million years



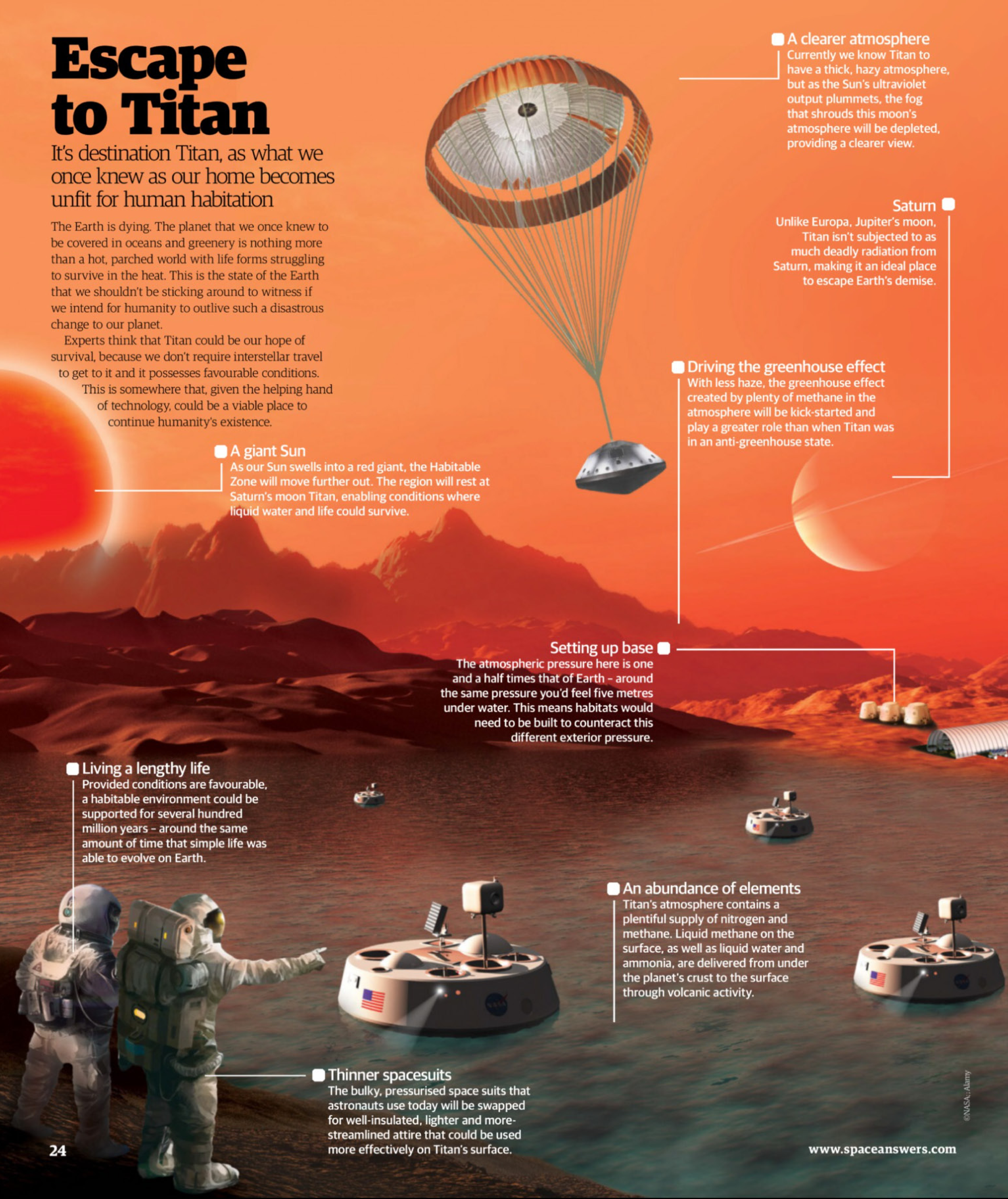
The Atlantic and Indian Oceans will close and North America will impact with Africa, taking on a more southern position. South America will wrap Africa's southern tip and Patagonia will meet Indonesia. The Pacific will have grown to encircle half the Earth.

Escape to Titan

It's destination Titan, as what we once knew as our home becomes unfit for human habitation

The Earth is dying. The planet that we once knew to be covered in oceans and greenery is nothing more than a hot, parched world with life forms struggling to survive in the heat. This is the state of the Earth that we shouldn't be sticking around to witness if we intend for humanity to outlive such a disastrous change to our planet.

Experts think that Titan could be our hope of survival, because we don't require interstellar travel to get to it and it possesses favourable conditions. This is somewhere that, given the helping hand of technology, could be a viable place to continue humanity's existence.



A clearer atmosphere
Currently we know Titan to have a thick, hazy atmosphere, but as the Sun's ultraviolet output plummets, the fog that shrouds this moon's atmosphere will be depleted, providing a clearer view.

Saturn
Unlike Europa, Jupiter's moon, Titan isn't subjected to as much deadly radiation from Saturn, making it an ideal place to escape Earth's demise.

Driving the greenhouse effect
With less haze, the greenhouse effect created by plenty of methane in the atmosphere will be kick-started and play a greater role than when Titan was in an anti-greenhouse state.

A giant Sun
As our Sun swells into a red giant, the Habitable Zone will move further out. The region will rest at Saturn's moon Titan, enabling conditions where liquid water and life could survive.

Setting up base
The atmospheric pressure here is one and a half times that of Earth – around the same pressure you'd feel five metres under water. This means habitats would need to be built to counteract this different exterior pressure.

Living a lengthy life
Provided conditions are favourable, a habitable environment could be supported for several hundred million years – around the same amount of time that simple life was able to evolve on Earth.

An abundance of elements
Titan's atmosphere contains a plentiful supply of nitrogen and methane. Liquid methane on the surface, as well as liquid water and ammonia, are delivered from under the planet's crust to the surface through volcanic activity.

Thinner spacesuits
The bulky, pressurised space suits that astronauts use today will be swapped for well-insulated, lighter and more-streamlined attire that could be used more effectively on Titan's surface.

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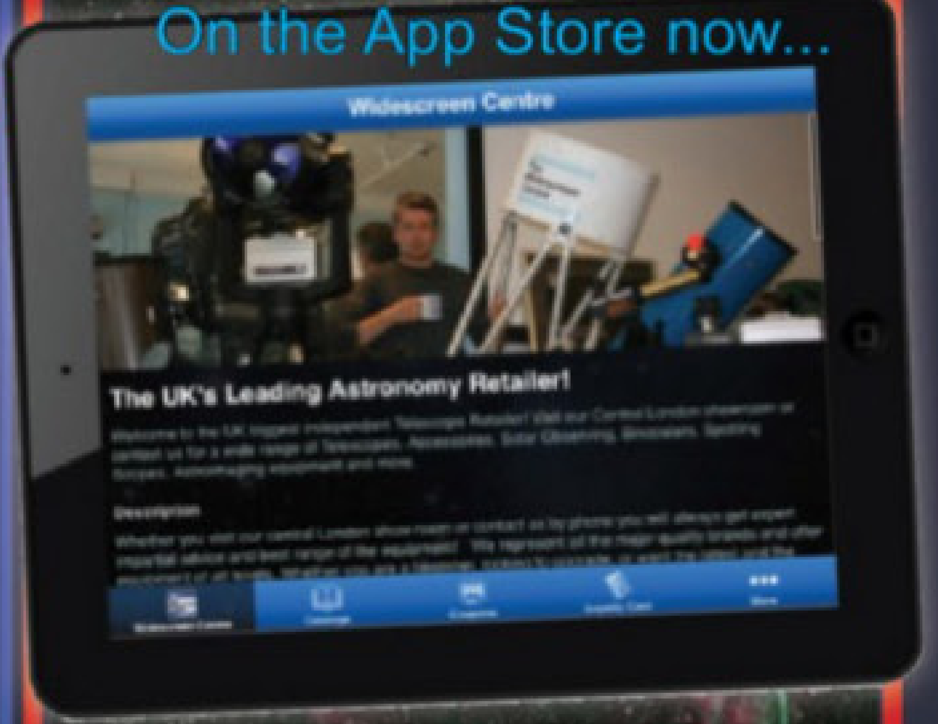

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New Worlds mission

By putting a huge umbrella into space, we could come closer to finding extraterrestrial life

The question of whether life exists on other planets is one that scientists frequently ponder, but have so far failed to answer. Hoping to change this is the New Worlds mission that, while still in the early phases of development following years of research, is likely to bear fruit in the near future.

One of the problems with observing extrasolar planets is the amount of light emitted by the parent star they orbit. When scientists use a telescope to look deep into space, they find the brightness of these stars drowns out the light from the orbiting planets. They still see the more-intense glow of larger planets, but the smaller ones are virtually impossible to spot. Since those tinier planets are, like Earth, more likely to contain signs of life, it means experts risk missing potential life-supporting worlds.

Dr Webster Cash, of the University of Colorado at Boulder, has devised a method to combat this problem. He proposes using a starshade, effectively a large blocker spacecraft that would be placed between the telescope and the target star. It would prevent light from the star reaching the telescope that would, in effect, be cast within a shadow. Just as a ball heading your way from up high on a bright day is better seen if you hold your hand to block the sunlight, so the planets orbiting their parent star are brought into view when the brighter light is blocked.

In 2013 NASA created a mockup of the starshade. The initial plan had been to produce a round disc, but this caused a problem with diffraction. When light from the parent star hits a round circle, it will diffract around the edge. Not only does this give a halo-like glow but it also drowns out the dimmer light of the smaller extrasolar terrestrial planets being sought, because it remains so bright.

The idea is to make the starshade look like a series of slit petals, each one sitting around the inner disk. Since the perimeter shape of the object the light is hitting governs diffraction, this design controls the way the light waves of the star behave, drastically cutting diffraction. Because the starshade will be tilted when put into space, the light from our own Sun will not disrupt the telescope's view of the extrasolar planetary system either.

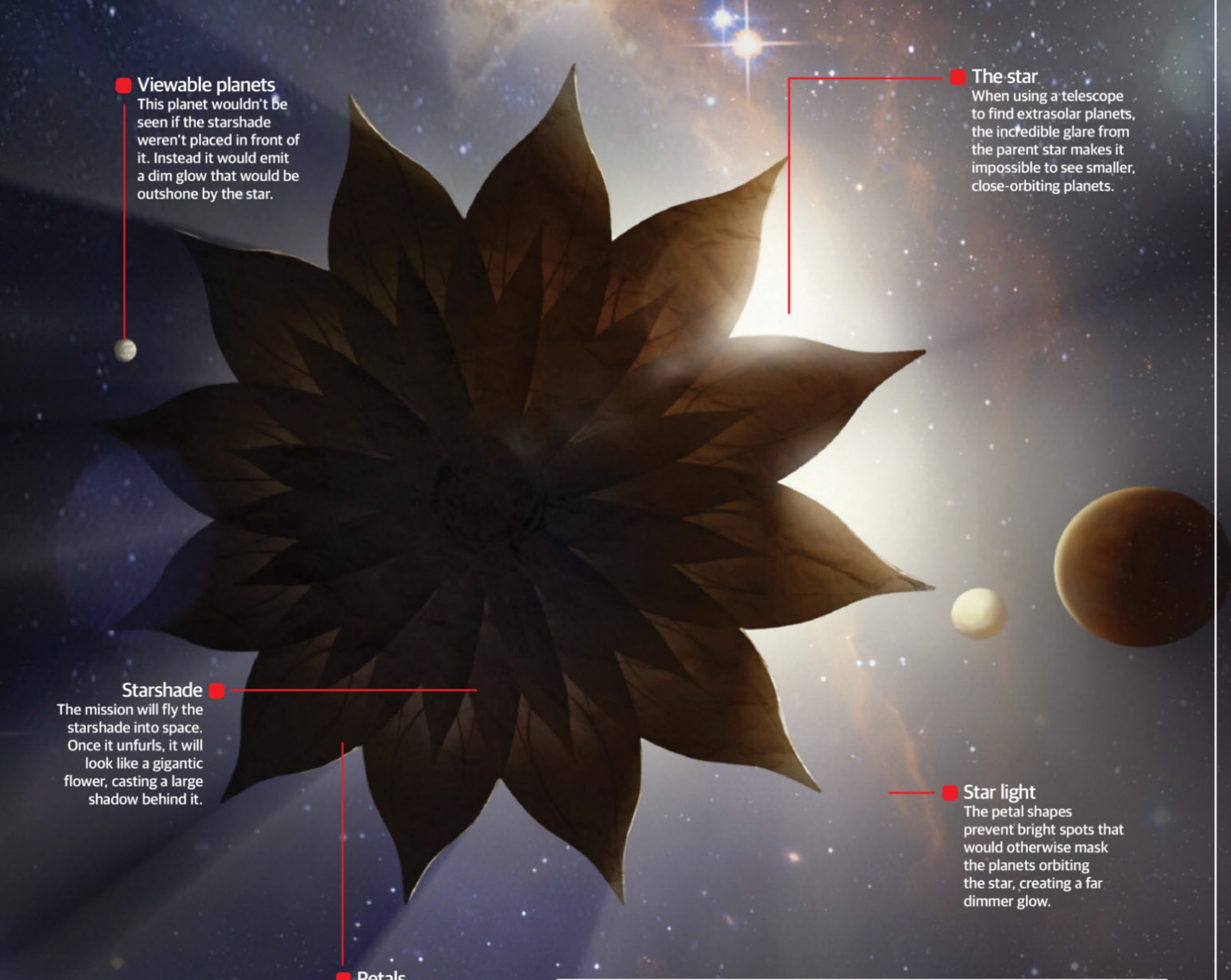
Although the proposal is to fly the starshade and the telescope into space in formation, it's more likely that the telescope will be sent up first and the starshade will follow at a later date. Though a launch date is far from being confirmed, the mission concept is being put together and should be complete by 2015. The team behind it is conscious of cost – with a budget of around £1.8 billion ($3 billion) – so it'll either work with an existing collector, such as the James Webb Space Telescope, or a four-metre (13-foot) telescope likely to be built in the future.

This won't be an easy mission, as the starshade will be sent to space in a folded state before unfurling. It also needs to be aligned with a telescope around 200,000 kilometres (124,000 miles) away. With little room for error and the need to maintain alignment, so much could go wrong. If the mission enables scientists to see planets they'd otherwise miss, enabling them be to analysed for water vapour, carbon dioxide and oxygen, the big question of the universe could be answered soon. ■

> "It needs to be aligned with a telescope around 200,000 kilometres away"

Distances
Obtaining the right distance between the stars, starshade and telescope is vital. There's little room for error, as the device sits 200,000km (124,000mi) away from the starshade.

The telescope
A telescope will sit behind the starshade in the dark. The starshade acts as a barrier between the telescope and the star.



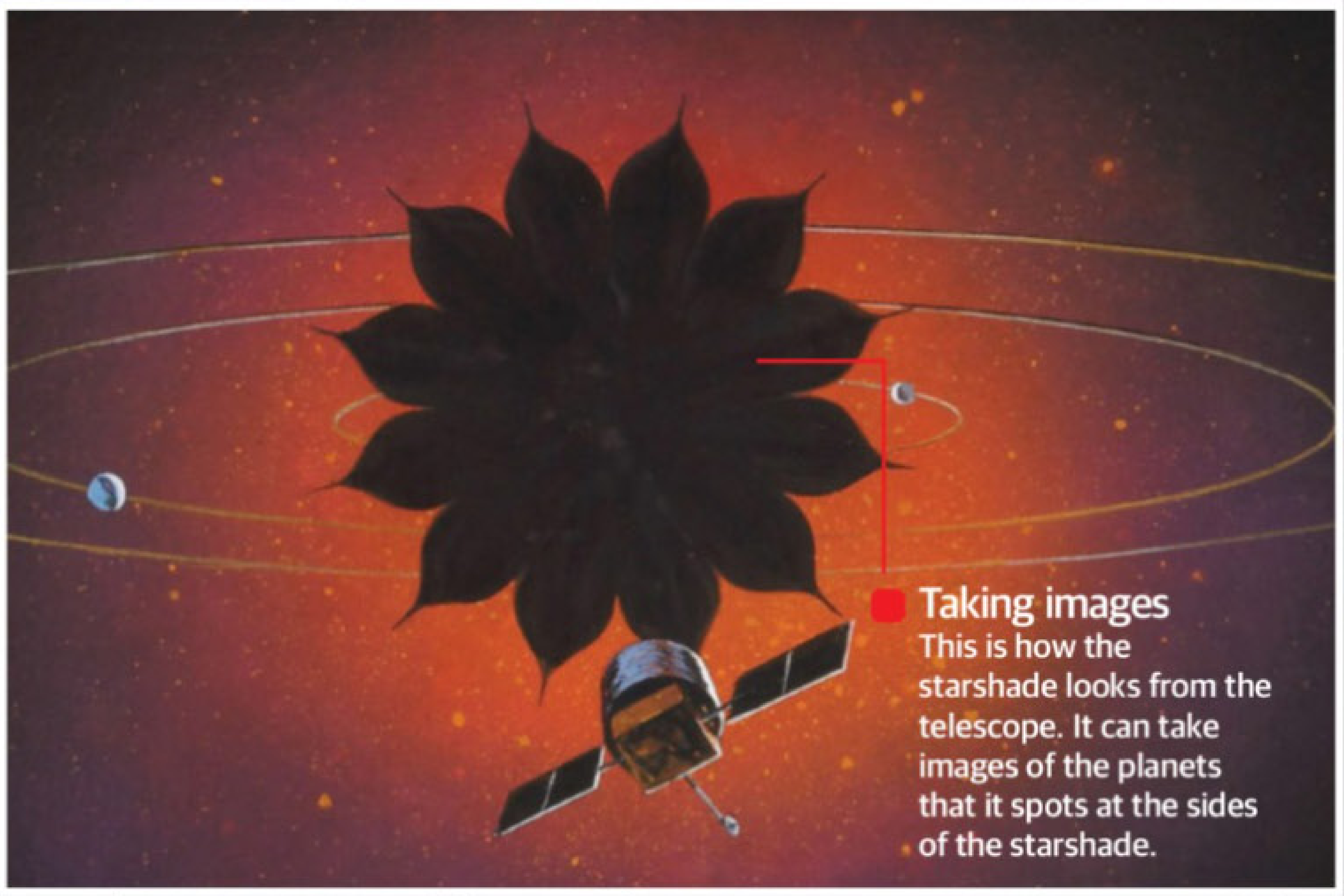
Viewable planets
This planet wouldn't be seen if the starshade weren't placed in front of it. Instead it would emit a dim glow that would be outshone by the star.

The star
When using a telescope to find extrasolar planets, the incredible glare from the parent star makes it impossible to see smaller, close-orbiting planets.

Starshade
The mission will fly the starshade into space. Once it unfurls, it will look like a gigantic flower, casting a large shadow behind it.

Star light
The petal shapes prevent bright spots that would otherwise mask the planets orbiting the star, creating a far dimmer glow.

Petals
If the starshade were round, diffraction would occur and the rippling light would still hamper the telescope's vision, so petals solve the issue.



Taking images
This is how the starshade looks from the telescope. It can take images of the planets that it spots at the sides of the starshade.

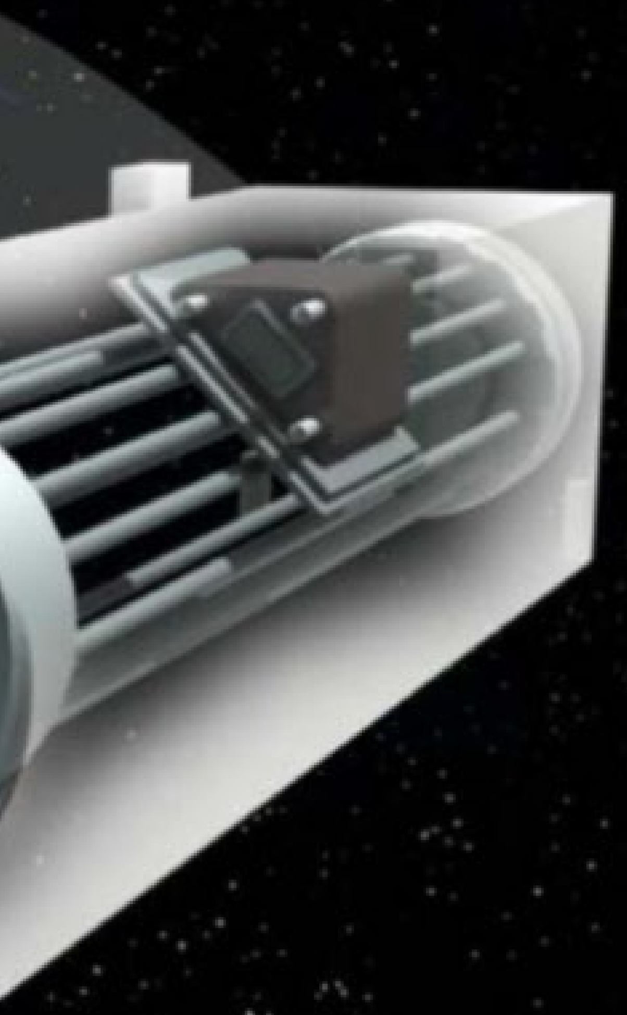
© Jay Wong

Quest to conquer space

10 WAYS TO CONQUER SPACE

It's the hardest thing humanity has ever attempted, but the technology to pull it off is finally within our grasp

Written by Luis Villazon



We went to the Moon not because it is easy, but because it is hard. 45 years later, it seems harder than ever. Many Saturn V components are no longer manufactured and the largest rockets currently in service can only lift payloads a fifth of the size.

Although manned exploration has been stuck in low Earth orbit since Apollo, scientists haven't been idle. Technologies tested on the International Space Station have vastly improved the computing, communication and life-support capabilities of modern spacecraft, while unmanned probes have mapped our solar system in great detail. As global interest gathers momentum, we are now ready to take the next leap: to the planets.

A spacecraft comprises dozens of different subsystems to propel it to its destination, land intact and protect the crew during the journey. Over the following pages we'll show you ten of the most promising technologies currently being developed by NASA and the European Space Agency for missions beyond Earth orbit.

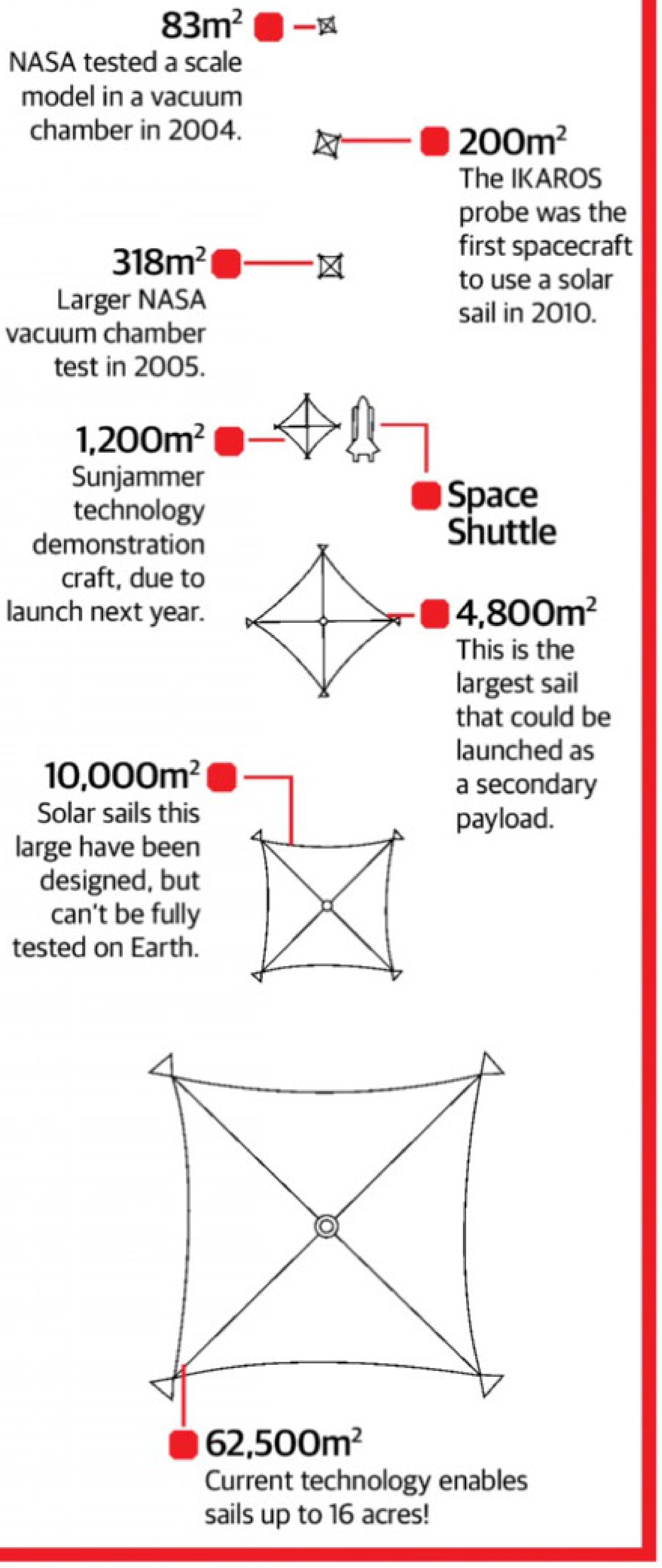
Some of these are already being tested aboard the ISS, while others will be launched as demonstration missions next year. Even the most speculative design concepts here use components and engineering that have already been successfully flown to space. A manned mission to Mars will be extremely challenging, but it isn't science fiction any longer.

Getting there

Imagine the Earth as an orange. At this scale, the Moon would be a small grape just under three metres (ten feet) away, but Mars would be a walnut about 1.6 kilometres (one mile) distant. Interplanetary space is huge and almost all of it is empty. Just crossing that void is an enormous undertaking and when you get to the other side, you've got to slow down from 21,000 kilometres (13,000 miles) an hour to zero in just seven minutes. Less than half of all the probes launched to Mars in the 1960s and 70s survived the journey, but the success rate has since improved thanks to better engineering and technology.

The Sun's rays push with a force a million times weaker than a light breeze on Earth

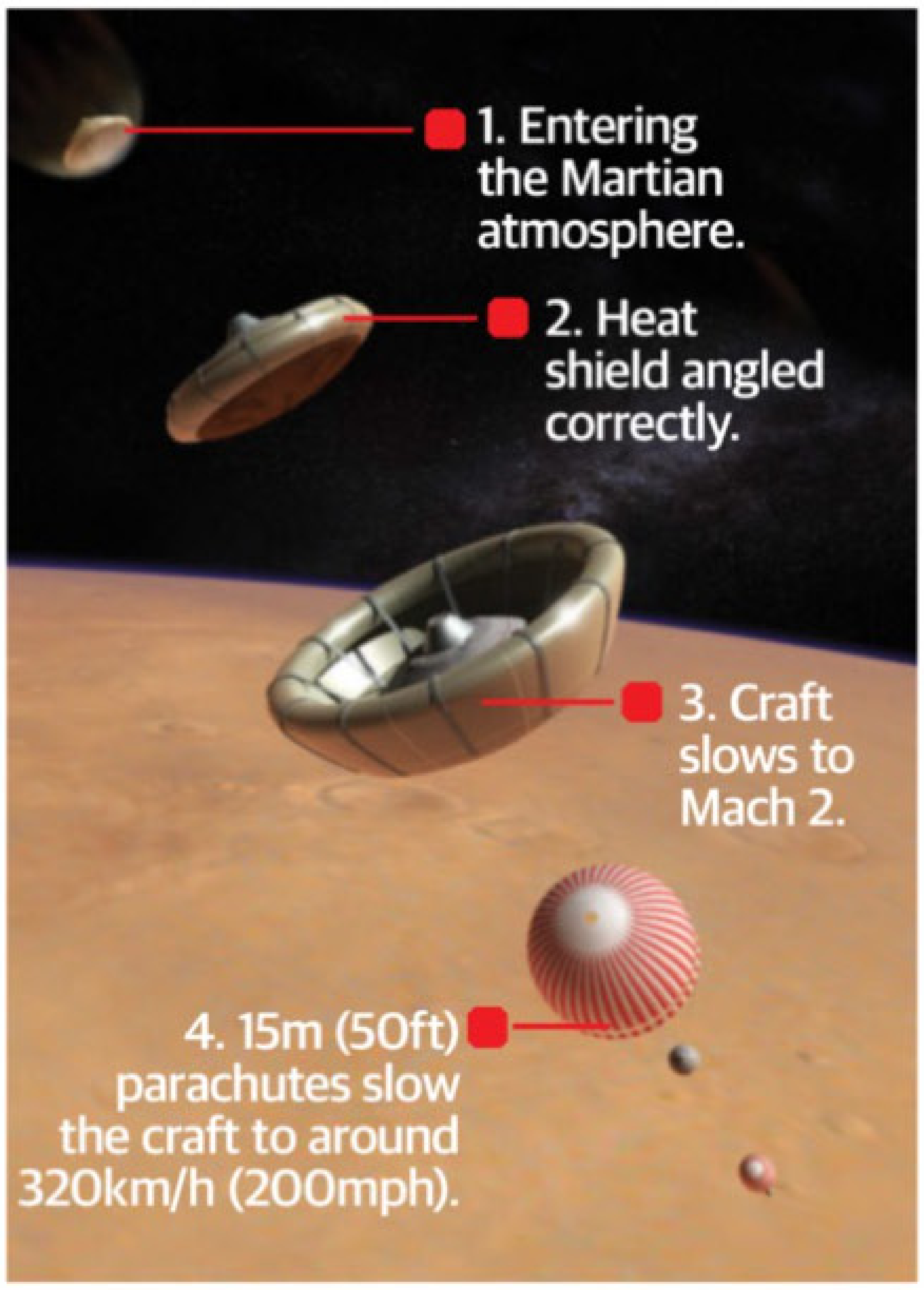
Solar sail comparison


83m²
NASA tested a scale model in a vacuum chamber in 2004.
200m²
The IKAROS probe was the first spacecraft to use a solar sail in 2010.
318m²
Larger NASA vacuum chamber test in 2005.
1,200m²
Sunjammer technology demonstration craft, due to launch next year.
Space Shuttle
4,800m²
This is the largest sail that could be launched as a secondary payload.
10,000m²
Solar sails this large have been designed, but can't be fully tested on Earth.
62,500m²
Current technology enables sails up to 16 acres!

1 Solar Electric Propulsion

The chemical rockets used on most spacecraft today produce thrust by burning fuel and oxidiser in a chemical reaction and expelling the exhaust gasses backwards. This produces very high thrust but uses a lot of fuel and some of the thrust is burned simply to accelerate the mass of the fuel. Solar Electric Propulsion, also known as an ion drive, achieves much more-efficient thrust by doing away with the chemical reaction. Instead, the Xenon gas propellant is positively charged by bombarding it with electrons in a magnetic chamber and then accelerated with a negatively charged grid. As the atoms leave the exhaust nozzle, they're travelling at 144,840 kilometres (90,000 miles) per hour. Although the thrust from SEP can only lift a sheet of paper, it's ten times more-efficient than chemical rockets.

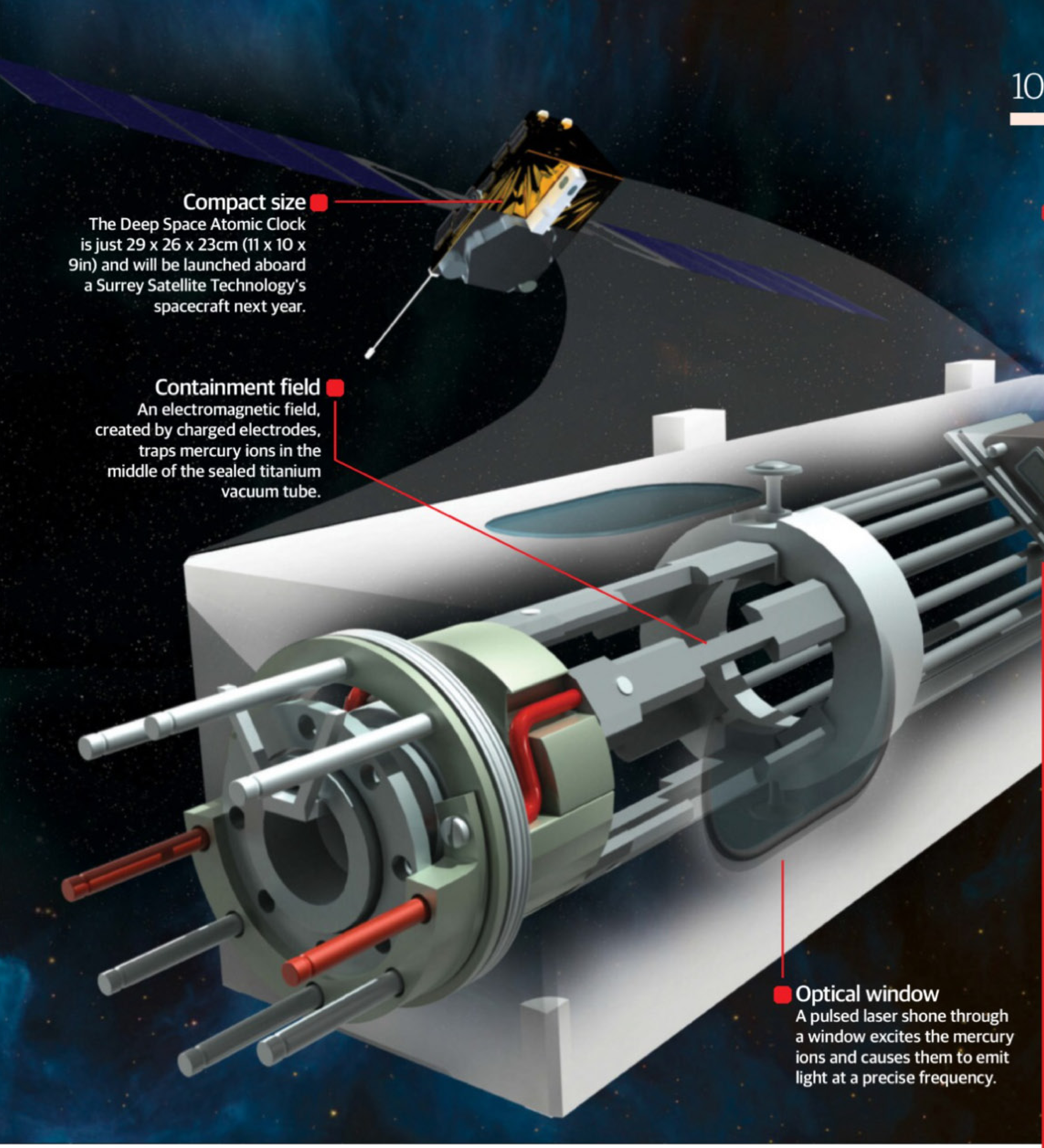
Solar sails offer even better efficiency by doing away with propellant altogether, with the reflective material harnessing the momentum of light itself. As the Sun's rays bounce off the sail, the deflected photons impart a tiny but constant force. Over several months or years the gentle thrust from these ultra-efficient propulsion methods can accelerate a spacecraft to interplanetary – or interstellar – speeds.


1. Entering the Martian atmosphere.
2. Heat shield angled correctly.
3. Craft slows to Mach 2.
4. 15m (50ft) parachutes slow the craft to around 320km/h (200mph).

2 Planetary descent

Mars has an atmospheric at least 60 times less dense than Earth's, but this isn't enough to slow a spacecraft down using parachutes alone. The Mars Curiosity rover used a combination of parachutes and rockets, but even then the landing site was restricted to the lowlands of the Gale crater, to increase the amount of atmospheric braking available. NASA has used the same design for every Mars mission since the Viking landers. Now new inflatable aerobrakes and 30.5-metre (100-foot) parachute canopies are being developed to enable heavier payloads and more-accurate landings, but they'll also enable missions to target higher-altitude terrain.

Testing entry, descent and landing (EDL) tech is tricky because it's hard to simulate the Martian atmosphere. NASA has used a rocket sled to drag parachutes at supersonic speeds, but the rocket motors used for the final phase of the landing can only be fully modelled in computer simulations. NASA supercomputers use 900 processors running in parallel to simulate the complex fluid dynamics.



Compact size
The Deep Space Atomic Clock is just 29 x 26 x 23cm (11 x 10 x 9in) and will be launched aboard a Surrey Satellite Technology's spacecraft next year.

Containment field
An electromagnetic field, created by charged electrodes, traps mercury ions in the middle of the sealed titanium vacuum tube.

Microwave detector
These optical ticks are converted to microwaves and counted to precisely record the passage of time. The clock loses a nanosecond every ten days.

Optical window
A pulsed laser shone through a window excites the mercury ions and causes them to emit light at a precise frequency.

3 Precise navigation

In space the only way to measure distance is by measuring time. Without accurate clocks, spacecraft can't measure their speed relative to anything else and ground control can't compensate for the time it takes to send radio messages across the huge distances between planets.

Atomic clocks have long provided the accuracy that space missions require, but until now the best ones have all been on the ground. This means the timing signals need to be beamed up to each spacecraft, which introduces errors and reduces the number of spacecraft that can be controlled at once. The Deep Space Atomic Clock (DSAC) is a miniaturised version of the most accurate clock available on Earth. It's packaged in a housing that's rugged enough to withstand the trip to space, while still only weighing 17.5 kilograms (39 pounds). When it launches in 2015, it will be in orbit for a year to calibrate and verify its own performance against the most accurate clocks currently in space – those on GPS satellites. However, DSAC is over ten times more accurate than GPS and will eventually enable spacecraft to determine their position and speed, completely independently of ground control.

This is important, because the further we venture from Earth, the greater the communication delay. Depending on the relative position of the planets, it can take anything from 3 to 22 minutes for radio signals to travel from Earth to Mars. That's far too long for real-time control of orbital manoeuvres. Even worse, spacecraft are cut off from Earth every time they orbit around the far side of another planet. Whether a mission is manned or robotic, it simply isn't realistic for spacecraft to depend on timely instructions from Earth. The DSAC is a key technology that will enable precise and autonomous navigation.

> "Without accurate clocks, spacecraft can't measure their speed"

Are we ready for Mars?

Richard Osborne, consultant for Reaction Engines Ltd and fellow of the British Interplanetary Society

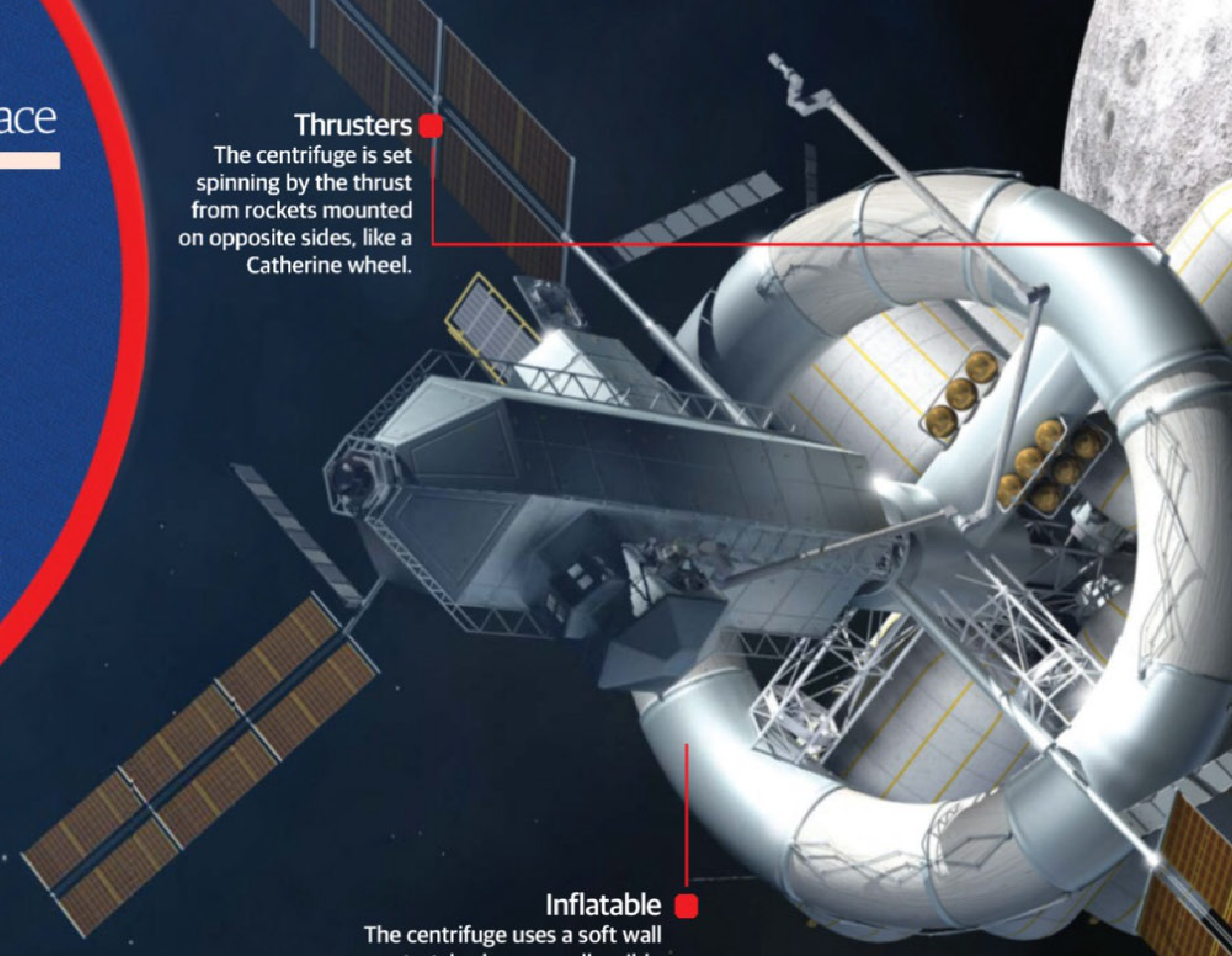
What advances are needed for interplanetary travel?
We need nuclear-powered ion engines, nuclear thermal rockets, then eventually nuclear fusion and antimatter-powered rocket technology. Nuclear thermal rockets would get us to the nearest planets in months, while nuclear-fusion rockets would be faster still.

Is navigating to another planet particularly challenging?
The mathematics and physics behind navigating to other planets from the Earth… is based on well-established principles of physics [but] the calculations [have] to be very accurate to start with… and the slightest error can result in spacecraft being hundreds or thousands of kilometres off course.

What are the challenges of landing on Mars?
The Martian atmosphere is… located in a much thinner layer, much closer to the surface… Any landing for a manned mission would have to use parachutes to slow down the descent, followed by a rocket descent and landing…

Surviving the journey

Although we've flung our machines to the edges of the Solar System, no human has ever ventured beyond the Moon. The ISS has given scientists and engineers a chance to explore some of the challenges of keeping astronauts safe and healthy in space. A single round-trip to Mars would rival the current endurance records for time in space. Nautilus-X is a concept vehicle developed by NASA with lots of life-support technologies that could sustain crews for up to two years at a time. It's thought to cost around $3.7 billion (£2.2 billion).



Thrusters
The centrifuge is set spinning by the thrust from rockets mounted on opposite sides, like a Catherine wheel.

Inflatable
The centrifuge uses a soft wall stretched over a collapsible articulated skeleton that can be inflated once in space.

4 Zero-G compensation

While floating around in microgravity might seem like the biggest perk of life aboard a spaceship, it's also very bad for your health. Astronauts can lose as much as five per cent of their muscle mass per week in space and decreased bone densities can take years to recover after returning to Earth. Zero-gravity conditions also increase the fluid pressure on the brain, which leads to eyesight problems at the same time as reducing the total blood volume, which causes heart muscles to atrophy. Astronauts currently on the International Space Station exercise for two hours every day but it's still not enough.

We don't fully understand the way that the body reacts to microgravity yet, but it's possible that no amount of running on a treadmill in an elasticated harness will substitute the universal pull of gravity. A spinning centrifuge compartment, like the one proposed by NASA for the Nautilus-X long-duration spacecraft, could use centrifugal force to mimic gravity. However, it would need to be big – even a 12-metre (39-foot) diameter ring spinning at 10rpm would only produce 69 per cent of Earth's gravity. This could keep astronauts conditioned for a trip to Mars, as its gravity is only 38 per cent of Earth's.

5 Radiation shielding

Interplanetary space is bathed by radiation from two distinct sources. The Sun mainly blasts us with waves of high-energy protons accelerated by solar flares, while cosmic rays consist of a thinner stream of extremely high-energy atomic nuclei propelled by supernova explosions from beyond the Solar System.

Here on Earth we're safely protected by the atmosphere and even astronauts in low orbit also receive some shielding from the Earth's magnetic field. Once you travel beyond that, radiation levels quickly build up. Solar protons can be blocked by the aluminium skin of the spaceship itself, but the strange thing about galactic cosmic rays is that physical shielding can actually increase the radiation dose. This is because the heavy particles have so much energy that they trigger a cascade of secondary radiation from the atoms of the aluminium shield.

Hydrogen atoms don't generate secondary radiation, however, so materials that are rich in hydrogen, like water, work much better. Some of this could be water that's needed for life support in any case, stored as cavity insulation in the hull.

To provide a thick enough shield, spacecraft would need to bring along a lot of extra water, which is more mass that must be accelerated by the engines. The alternative is to use active shielding to deflect the path of dangerous particles. Galactic cosmic rays are positively charged, so they could be deflected by a positively charged electrostatic shield. However, this would require a huge amount of energy to offset the constant neutralising effect of deep-space electrons. Magnetic shields are more promising, but magnetic fields five to ten times stronger than those in an MRI scanner would be needed. The long-term effects of human exposure to magnetic fields this strong aren't known and might actually be worse than the radiation.

Orion spacecraft

A double-walled plastic hull filled with water could block harmful cosmic rays. A mixture of different shielding might be needed for missions lasting for long periods

Travelling in style

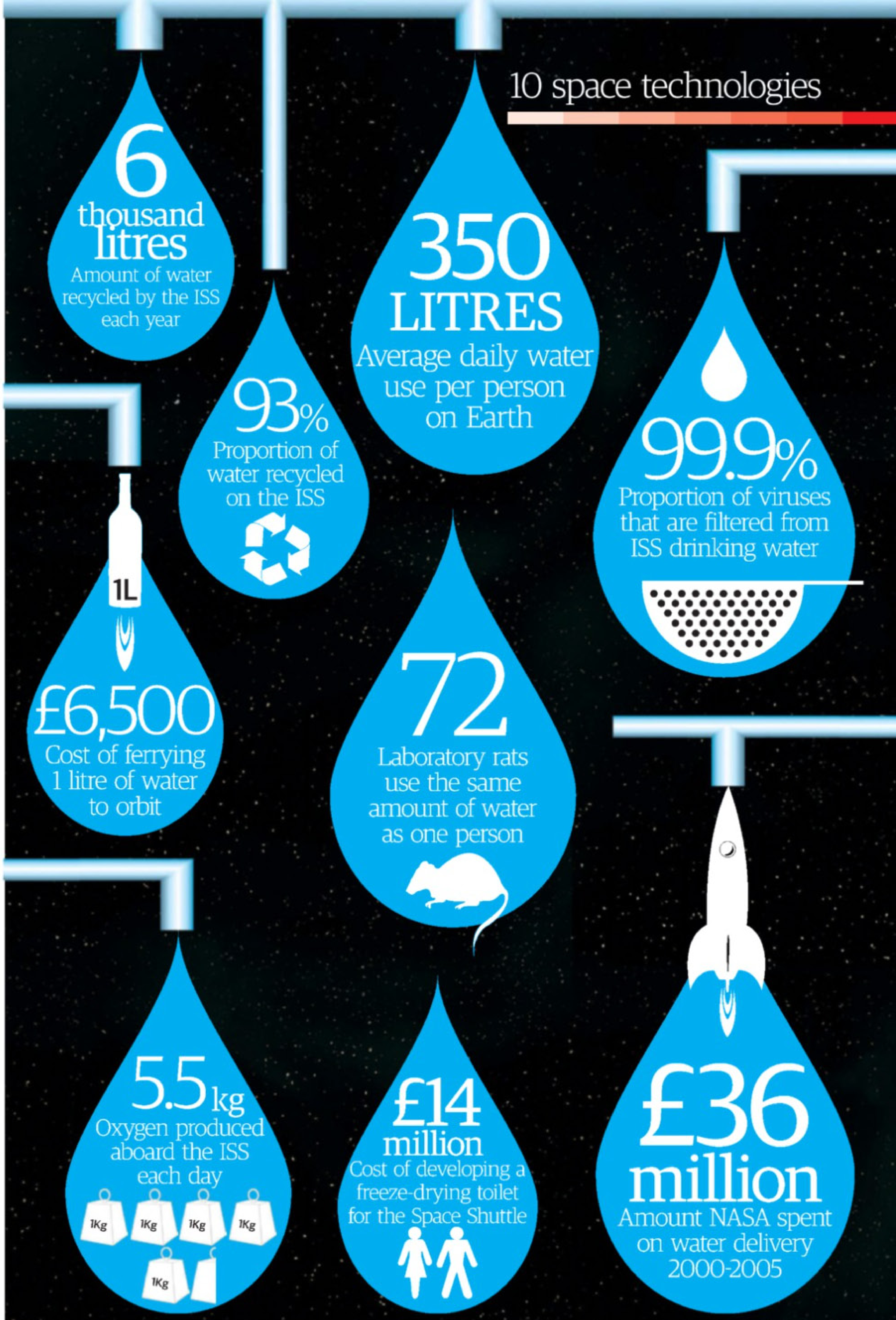
Mark Holderman, Nautilus-X architect & director of design

What is the minimum crew size for a mission that might last several years?
Bare-bones, skin-of-your-teeth, absolute minimum is a crew of nine: three each on, off or sleeping.

Is there anything we can't recycle in space?
A Closed-Loop Life-Support System can reach a high degree of efficiency, but there will always be some residue/waste. Nautilus-X will incorporate UV-sterilised human waste in a hydroponic garden to the greatest extent possible.

How does Nautilus-X protect the crew from radiation?
During the sleep period in the centrifuge they will be residing in an individual sarcophagus that utilises a fluffed-leading material and an active magnetic bottle to approximate the Earth's magnetosphere. During their off-time, the crew will be in a volume that's encased in a hydrogen slush. The [on-duty] crew members will be wearing Internal Vehicular Activity (IVA) suits [made of] material specific for blocking background radiation.

Flywheel
This spins in the opposite direction to cancel out the torque, so that the rest of the spaceship doesn't spin.


6 thousand litres
Amount of water recycled by the ISS each year
93%
Proportion of water recycled on the ISS
350 LITRES
Average daily water use per person on Earth
99.9%
Proportion of viruses that are filtered from ISS drinking water
1L
£6,500
Cost of ferrying 1 litre of water to orbit
72
Laboratory rats use the same amount of water as one person
5.5kg
Oxygen produced aboard the ISS each day
1Kg
1Kg
1Kg
1Kg
1Kg
£14 million
Cost of developing a freeze-drying toilet for the Space Shuttle
£36 million
Amount NASA spent on water delivery 2000-2005

6 Recycling air and water

Before 2009, the ISS could only recycle the small amount of moisture that was condensed from astronaut breath and sweat. Urine and waste water from washing were dumped overboard and replaced with water that was hauled into orbit in 41-kilogram (90-pound) bags during resupply missions. For a space station orbiting 370 kilometres (230 miles) up, that's expensive, but for a long-duration mission to another planet, it's simply out of the question.

Today's ISS uses a rack-mounted water treatment system that filters and distils water on demand. In microgravity, steam doesn't rise, so the keg-sized distillation drum is spun to separate the steam by centrifugal force. The processed water is cleaner than tap water on Earth but there's still a small amount of water lost from the system each day. Once efficiency improves from 93 to 95 per cent, the ISS will be able to obtain all the remaining water from the moisture present in food supplies.

Oxygen on long-duration missions is actually less of a problem. The Apollo and Shuttle missions generated the oxygen they needed as a by-product of the hydrogen fuel cells that generate electricity. Oxygen can also be produced by splitting water and venting the hydrogen into space.

Living and working in deep space

The crew of a deep-space mission or Mars colony will be small. Even with the relatively short six-month tours of duty aboard the ISS, NASA has found evidence that over time, astronauts begin to form their own clique and increasingly see mission control as their opponent. Astronauts will need to be psychologically screened, as well as kept motivated and happy during missions that could last several years

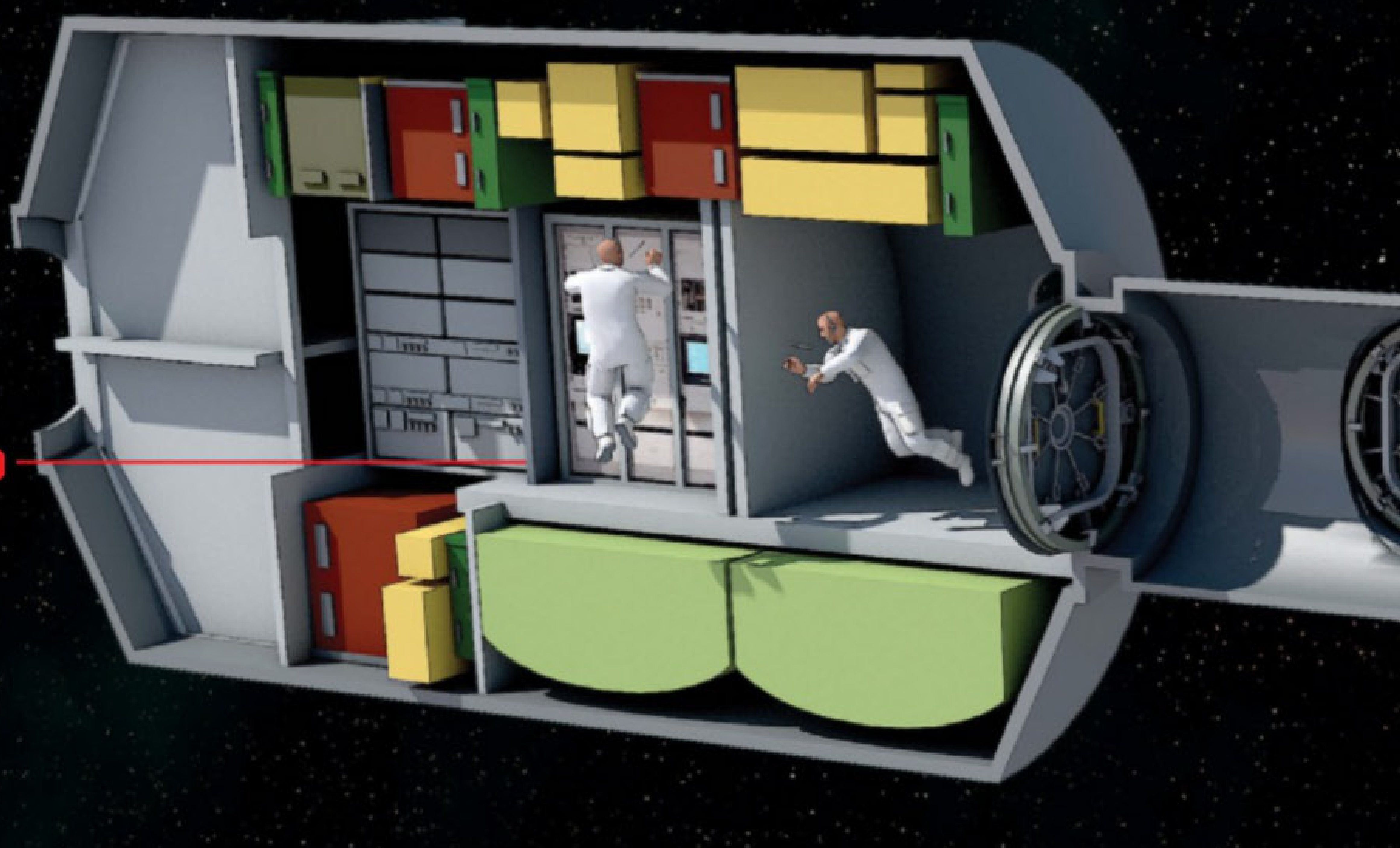
8 Deep Space Habitat

As well as missions straight to Mars and other planets, NASA has plans for space stations inside the orbit of the Moon as a stepping stone for even more-distant goals.

The Deep Space Habitat proposal has two versions. The basic model supports four crew for 60 days and would enable a semi-permanent base floating somewhere along the L1 or L2 Lagrange point. These are the points where the Moon and the Earth's gravity cancel each other out. A more-ambitious, 500-day version could be used to intercept near-Earth asteroids.

A spacecraft can effectively hover at this point in space indefinitely and provide a waypoint for future Lunar or Martian landing missions. Deep Space Habitat uses modules and technologies that have been extensively tested aboard the ISS and could be launched in sections. A fuel depot at the L1 Lagrange point would enable lander spacecraft to be launched from Earth with empty fuel tanks and collect fuel on the way. This would reduce their liftoff weight and could have a massive affect on the feasibility of regular supply flights to an off-world colony.

> "A more-ambitious, 500-day version could be used to intercept near-Earth asteroids"

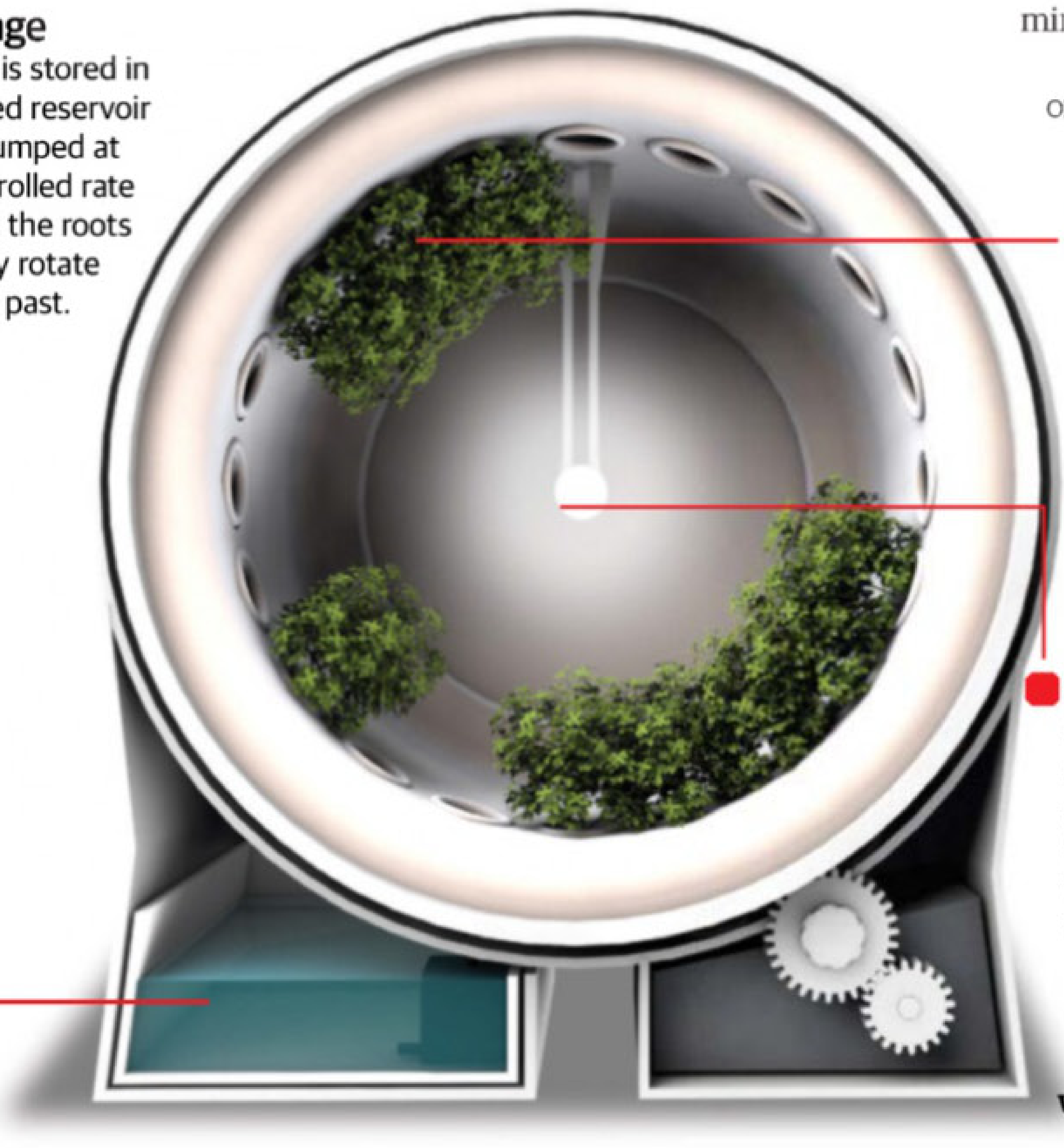


Main module
The main habitation module includes a Multi-Purpose Logistics Module, originally used by the Space Shuttle for deliveries to the International Space Station.

7 Growing food

A crew of nine astronauts on an 18-month round trip to Mars would consume around 16 tons of food, so saving mass by growing your own vegetables en route is certainly tempting.

The ISS has had its own mini research greenhouse since 2002 and the plants grown in space have recently been declared safe for human consumption. Scaling this up to produce even half of the food requirements of the astronauts would be difficult, however. Salad leaves can be grown in 30 days, but vegetables with significant calorie content take much longer, so you still need food supplies while you wait for the harvest. Long-term colonies on the surface of Mars would be less constrained by space, but Mars only receives half as much sunlight as Earth, so it would need to be augmented with artificial lighting. For missions shorter than 15 years it might still be cheaper to send regular food-supply ships.

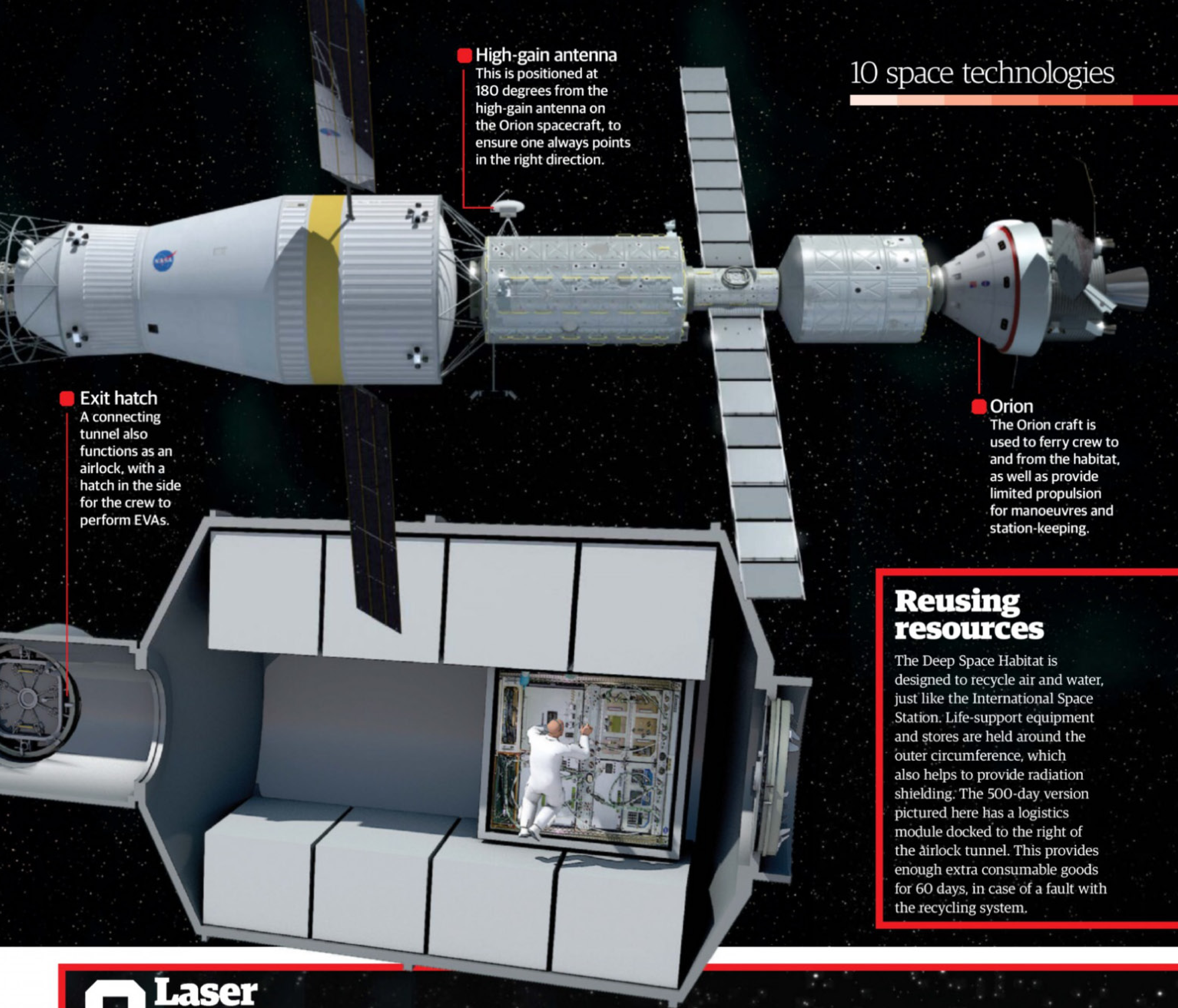


The Green Wheel is a miniature hydroponics system for the home, but it was originally designed by NASA for possible use in space.

Storage
Water is stored in a sealed reservoir and pumped at a controlled rate to wet the roots as they rotate slowly past.

Grid system
Plants grow in a coconut-fibre medium and emerge through a retaining grid. Even without gravity, they will grow evenly towards the light.

Centre light
A single LED light in the centre illuminates the entire inner circumference of the farm at once, with the optimal wavelengths for plant growth.



High-gain antenna
This is positioned at 180 degrees from the high-gain antenna on the Orion spacecraft, to ensure one always points in the right direction.

Exit hatch
A connecting tunnel also functions as an airlock, with a hatch in the side for the crew to perform EVAs.

Orion
The Orion craft is used to ferry crew to and from the habitat, as well as provide limited propulsion for manoeuvres and station-keeping.

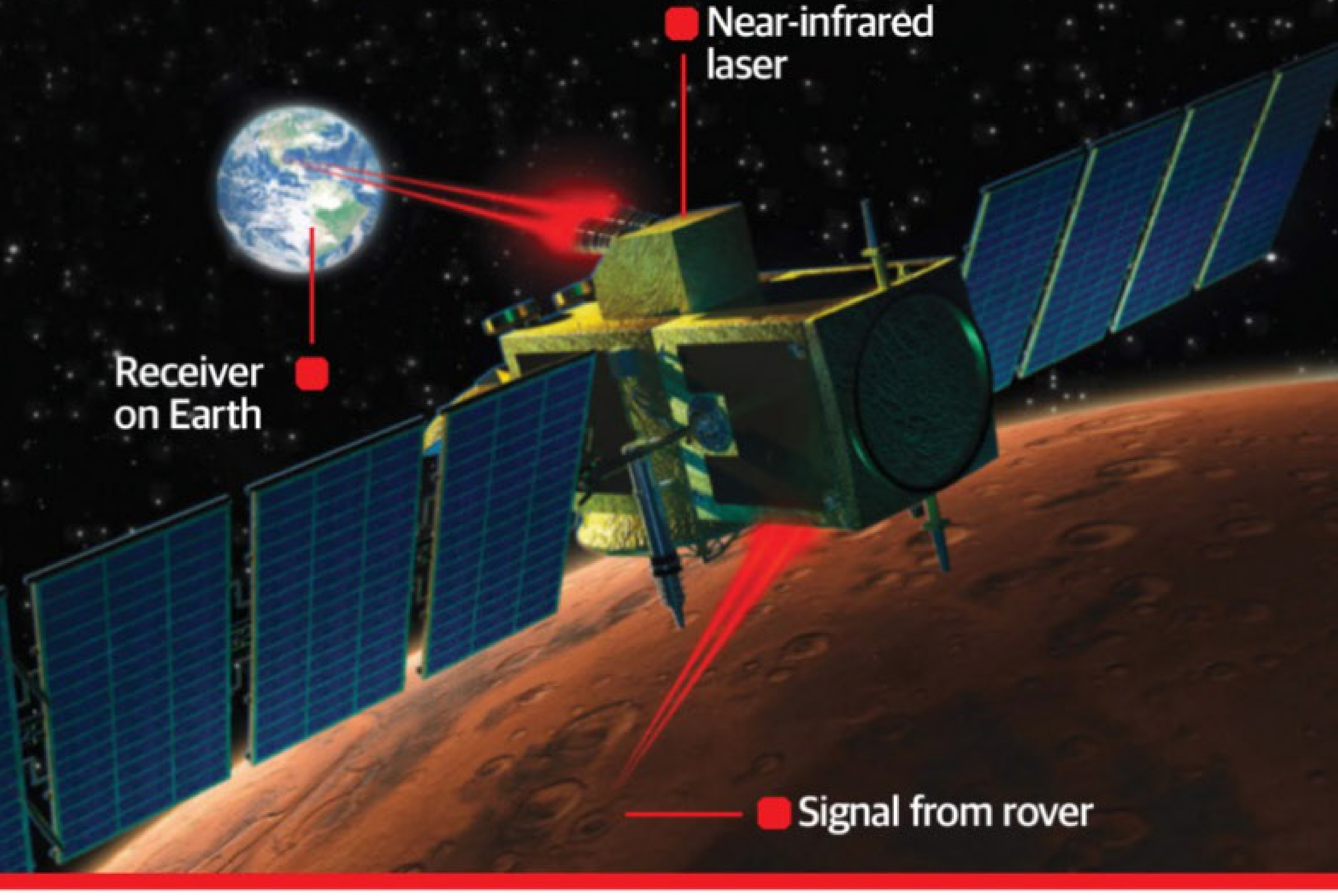
Reusing resources

The Deep Space Habitat is designed to recycle air and water, just like the International Space Station. Life-support equipment and stores are held around the outer circumference, which also helps to provide radiation shielding. The 500-day version pictured here has a logistics module docked to the right of the airlock tunnel. This provides enough extra consumable goods for 60 days, in case of a fault with the recycling system.

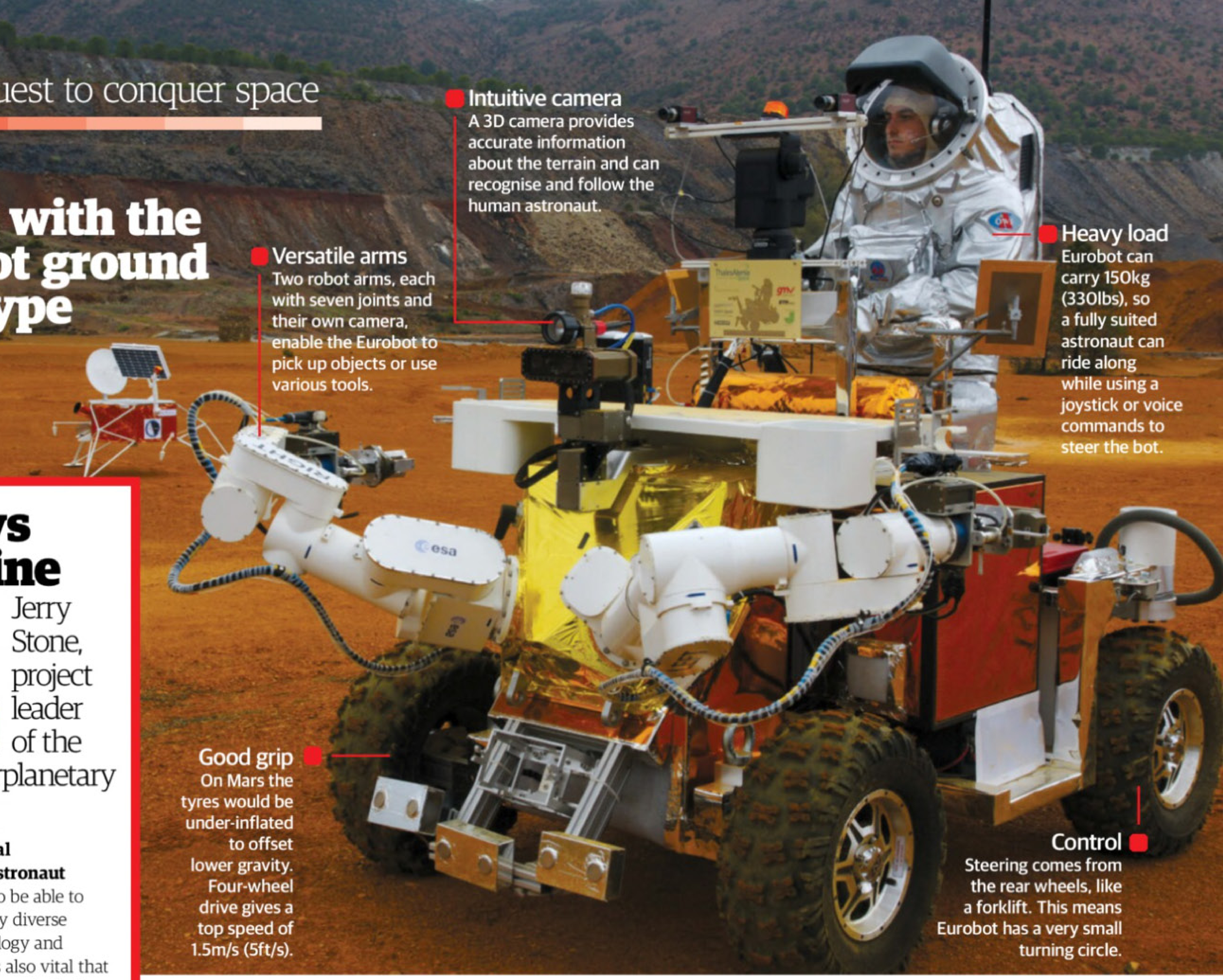
9 Laser Communications Relay

Whether you use radio waves or laser light, a communication signal can't travel faster than the speed of light, but the amount of information encoded in that signal can vary. The Lunar Reconnaissance Orbiter (LRO) currently mapping the surface of the Moon transmits data at 100 megabits per second. At that speed it takes several minutes to send a single high-res image. That's already slow enough to limit mission operations, but at Mars the problem becomes much worse. Mars can be 1,000 times further away than the Moon and signal strength decreases with the square of the distance, so it would be a million times weaker. If the LRO were sent to Mars, it'd take years to transmit the same image.

Lasers have the potential to improve on this in two ways. First, infrared lasers have much higher frequencies than radio waves, so they have higher bandwidths. Second, the beam can be focused much more precisely, reducing the signal attenuation. The Laser Communications Relay Demonstration is set to be around 10 to 100 times faster than the radio communications systems of the same size, with bandwidths of up to 1.25 gigabytes per second.



Riding with the Eurobot ground prototype



Intuitive camera
A 3D camera provides accurate information about the terrain and can recognise and follow the human astronaut.

Versatile arms
Two robot arms, each with seven joints and their own camera, enable the Eurobot to pick up objects or use various tools.

Heavy load
Eurobot can carry 150kg (330lbs), so a fully suited astronaut can ride along while using a joystick or voice commands to steer the bot.

Good grip
On Mars the tyres would be under-inflated to offset lower gravity. Four-wheel drive gives a top speed of 1.5m/s (5ft/s).

Control
Steering comes from the rear wheels, like a forklift. This means Eurobot has a very small turning circle.

Man vs machine

Jerry Stone, project leader of the British Interplanetary Society

Describe the ideal interplanetary astronaut
Astronauts need to be able to understand… many diverse areas, such as geology and medicine, [but] it's also vital that they tolerate life in a relatively confined area. As someone once said: "What we're looking for is a group of ordinary supermen!"

What are the advantages of a manned mission to Mars?
Robots move slowly and their decision-making capability is limited. An astronaut would only take three days to accomplish what it [has] taken the two rovers [Spirit and Opportunity] six months to achieve.

How can robots assist humans on interplanetary missions?
Robots can be used in areas that would be dangerous for astronauts or difficult to reach. If we are to truly explore space then both are necessary.

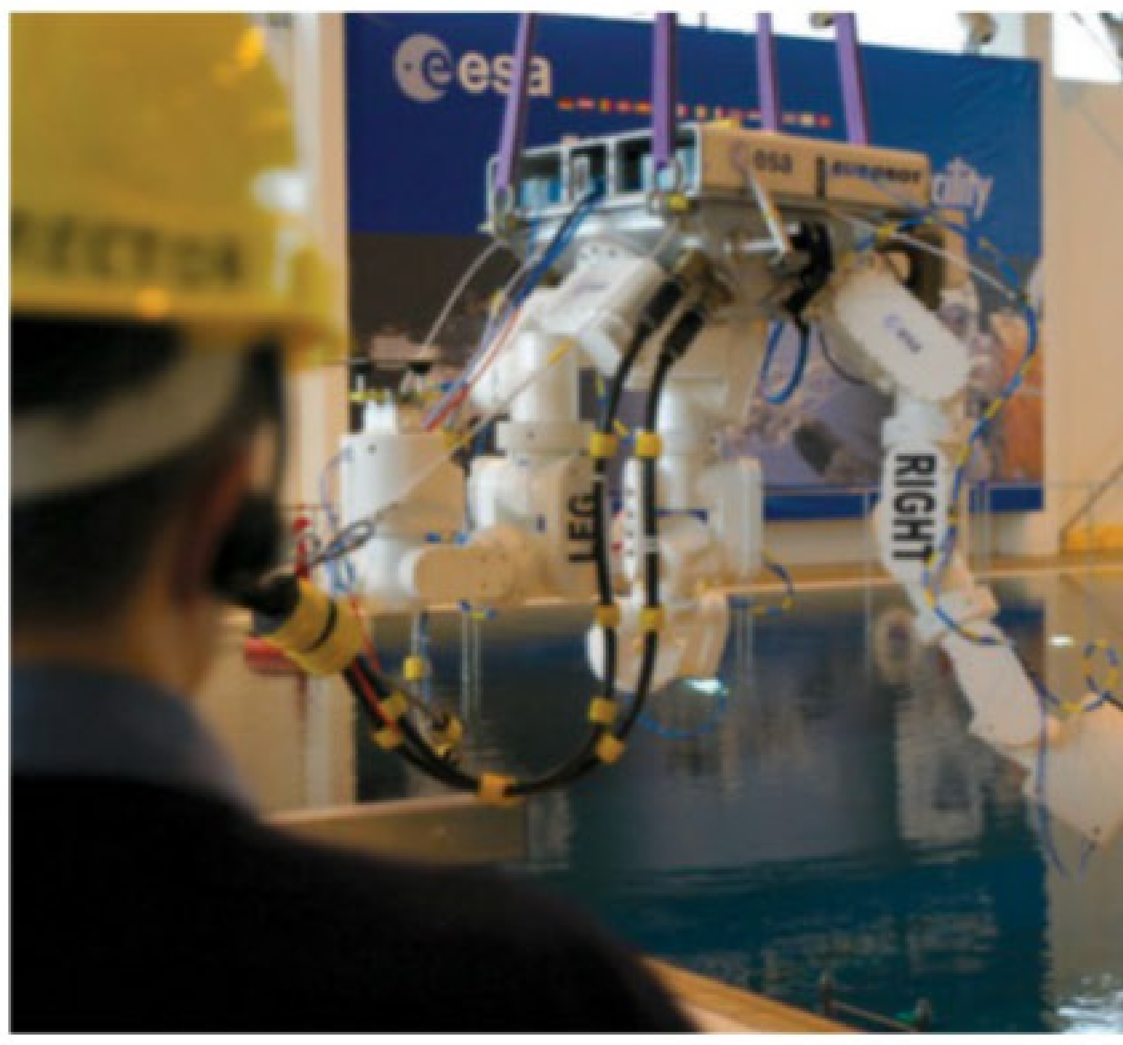
Can we rely on computers to be crew members?
We shouldn't worry about Robonaut going berserk! The real problem will be the limitations of its programming. It cannot decide that a rock looks particularly interesting and so it's going to spend more time investigating it.

10 Robotic explorers

Up to now robots have been used as a cheaper, more-expendable alternative to a human crew, but even manned missions will travel with a robot contingent in future. Robots can stay outside on the Martian surface and give crew a way to perform inspection and maintenance of the ship, or carry out simple science experiments without wasting time prepping for an EVA excursion. Current probes, like Mars Curiosity, move very slowly because they must be remotely controlled from Earth and communications delays make it hard to react to unexpected situations.

The European Space Agency is currently testing the Eurobot, which can be directly controlled using a Haptic Telepresence Exoskeleton. Astronauts wear a special harness around their arms that translates their actions into movements of the Eurobot's arms – complete with tactile feedback if it touches something. This effectively makes the robot into an extension of the astronaut's own body and may actually give them better freedom of movement than they would have inside a bulky pressurised spacesuit. A robot could even be an extra pair of hands for routine science operations, as well as a life-saver that can be sent out in the middle of a Martian sandstorm, for instance, to carry out critical repair work.

The DexArm robot arms used by Eurobot consume just 100 Watts of power but they can handle loads up to 500kg (1,100lbs) in orbit, or 26kg (57lbs) on the surface of Mars. Every joint has its own torque sensor so Eurobot always knows the exact position of its fingertips, to within 0.3mm (0.01in).



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Abell 33's cosmic proposal

The chance meeting between a planetary nebula and a bright star has produced this long-distance engagement

Diamonds are an astronomer's best friend, as this image caught by the Very Large Telescope (VLT) in Chile's Atacama desert shows. What the European Southern Observatory's telescopic sentry has captured is what appears to be something akin to a celestial diamond ring.

You would be forgiven for thinking that this eye-catching shot is some strange singular object hanging in a backdrop of deep space and stars. However, here you can see a meeting of two separate events coalescing to make this rare sight. Planetary nebula Abell 33 has just by chance aligned with super-bright foreground star HD 83535, suggesting a cosmic proposal.

What's striking about this particular shot is that Abell 33, located some 2,500 light years away, is almost perfectly round. It was formed when an aging star threw off its outer layers to create a beautiful, blue, ultraviolet bubble. This is something that's uncommon for planetary nebula, since impartial objects often disturb their symmetry.

The ultraviolet glow of planetary nebula Abell 33 pairs up with bright foreground star HD 83535 to propose with a celestial diamond ring

© ESO

HYPER

GIANT SUPERNOVAS

Hypergiants are among the largest and most luminous stars in the universe, but these massive bodies lead brief, brilliant lives that often end violently. They're also rare and difficult to study, but their elusiveness makes them all the more fascinating to astronomers

Written by Shanna Freeman

Stars spend the vast majority of their lives as dwarfs in the main sequence, fusing hydrogen into helium. Once they've used up their supply of hydrogen and leave the main sequence, however, the lives of stars can take very different turns depending on their mass. Hypergiant stars are so-called because they are all about extremes – massive, luminous and losing mass at a high rate.

Looking at the Hertzsprung-Russell diagram used to classify stars by spectral type, hypergiants are at the very top above supergiants. This must mean they're bigger and brighter than supergiants, right? Not necessarily. In the 1950s, astronomers A. David Thackeray and Michael Feast recommended the term super-supergiant to describe the most luminous supergiant stars. Supergiant stars have masses more than eight times that of the Sun and an absolute magnitude brighter than -5 (by comparison, the Sun's absolute magnitude is +4.83).

Thackeray and Feast suggested that the super-supergiant be a supergiant star with an absolute magnitude brighter than -7. Super-supergiant was changed to hypergiant, but that doesn't mean that hypergiant stars are always going to be more massive or more luminous than supergiants. In 1971, astronomer Philip Keenan suggested fine-tuning the definition of a hypergiant to include massive stars that are losing mass at a high rate or have an extended atmosphere. Hypergiants also have red-shifting (when their spectral light wavelength extends, or shifts to the red end of the spectrum), which gives them a shape called a P Cygni profile.

Dr. René Oudmaijer (School of Physics and Astronomy at the University of Leeds) states: "We still don't know how they lose mass, but one of the things that increases the rate of the loss is because they're so large the material on the outer parts isn't as tightly bound to the star's gravity as it was when it was smaller. It still needs a push to leave the star and current thoughts include pulsations and strong radiation of the star could give the material a little extra push as well".

Like supergiants, hypergiants are yellow, red, or blue. However, we don't know where these stars are located in terms of their lifespan – they may begin at many different luminosities and masses and be in different stages. In general, the blue hypergiants are the hottest, red are the coolest and yellow are somewhere in the middle. But many astronomers prefer to use the term hypergiant only for certain groups of stars that have other well-defined characteristics, or when talking about specific stars when their mass and luminosity are known.

There is also a group of stars with members that can sometimes be considered to be part-time hypergiants. These are called luminous blue variables, or LBVs, and are highly unpredictable, with variable cycles of spectra and brightness. This means some of them can be classified as hypergiants depending on where they are in the cycle. They can range from luminosity between 250,000 and one million times the Sun's strength, and a temperature between 10,000 and 25,000 Kelvin. LBVs may have outbursts and eruptions, with dramatic increases in luminosity and losses in mass. These eruptions are what may lead some LBVs to be classified as hypergiants. At times the outbursts have been so violent that they were initially thought to be supernovae. LBVs have very short lives of just a few million years, and there are just 20 of them listed in the *General Catalogue of Variable Stars*. However, not all of these are even considered LBVs any longer.

One of the well-known LBVs is P Cygni in the constellation Cygnus. It's one of the most luminous stars in the galaxy, with an estimated luminosity 610,000 times that of the Sun's and about 30 solar masses. P Cygni has been observed since 1600 CE and reports over the following century described large fluctuations in brightness and visibility. Since then it's had only minor fluctuations in brightness.

Blue hypergiants have a lot of similarities to LBVs in terms of luminosity and solar mass. However, they don't exhibit the variations that LBVs do. Because of this, some astronomers think blue hypergiants may evolve into LBVs, or vice versa. One of the best-known blue hypergiants is Zeta1 Scorpii, which has a huge luminosity as high as 850,000 solar masses. Located in the constellation Scorpius, Zeta^1 Scorpii is estimated to be shedding the equivalent of the Sun's mass every 640,000 years. It is visible to the naked eye as part of a double with Zeta^2 Scorpii, but they aren't a binary system - they just happen to lie in the same line of sight from Earth. However, Zeta^2 Scorpii is a smaller, orange giant star.

Red hypergiants are M-class and among the largest stars when measured by volume. They have very low surface temperatures in comparison with blue hypergiants, but are some of the largest known stars by radius. VY Canis Majoris, for example, has a radius almost 1,500 times that of the Sun. There's some controversy as to whether Canis Majoris is really the largest red hypergiant because determining the radius of very large stars can be difficult - they're losing a lot of mass, so their outer layers aren't completely gravitationally bound.

Yellow hypergiants have been the special focus of astronomers such as Eric Lagadec because they are some of the most luminous stars, as well as some of the rarest, in the galaxy. These hypergiants have extended atmospheres and began with up to 50 solar masses, but have lost up to half of their mass. They range from late A-class (bluish-white to white) to early K-class (orange). In the Hertzsprung-Russell diagram, yellow hypergiants occupy a region called the Instability Strip. As you might imagine from the name, stars in this range are mostly unstable and variable. Temperature-wise, they can range from 4,000 to 8,000 Kelvin. According to Lagadec, there "are about 15 known yellow hypergiants". There could be more in the galaxy, as we could have missed some

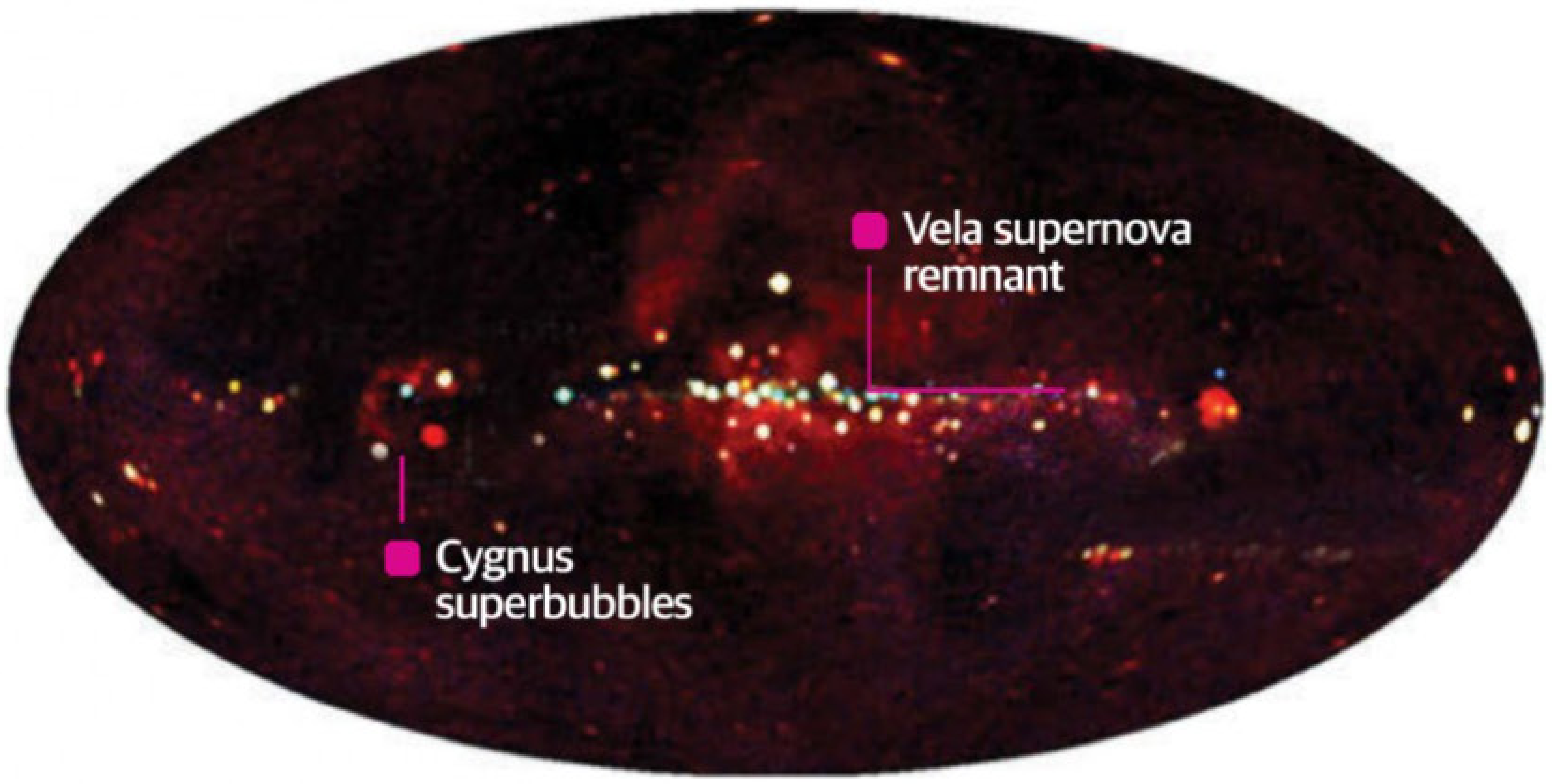
> "One of the best-known blue hypergiants is Zeta1 Scorpii, which has a huge luminosity as high as 850,000 solar masses"

Hypergiants in the Milky Way

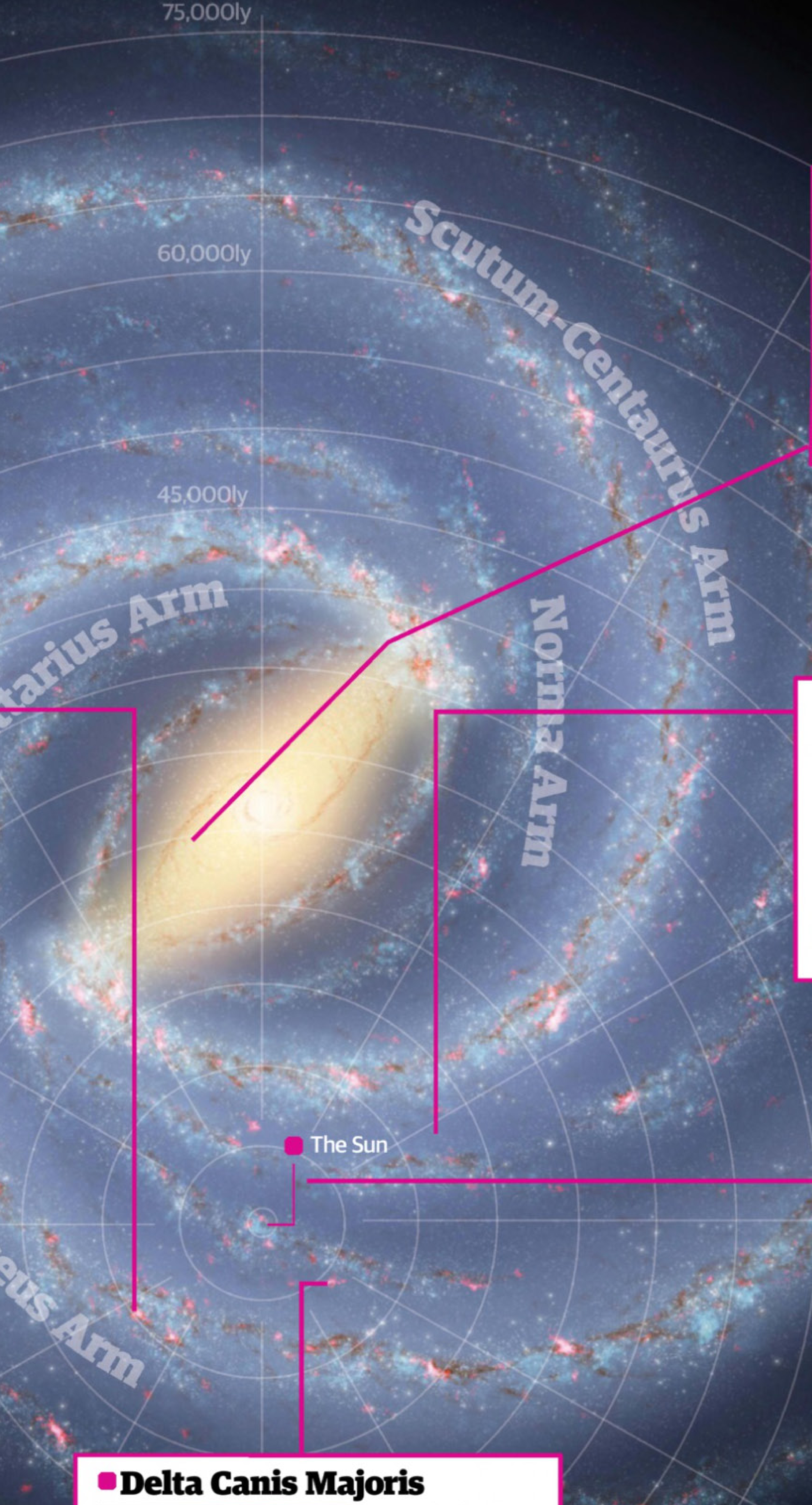
Rho Cassiopeiae

Rho Cassiopeiae is a yellow hypergiant star that can be seen with the naked eye because it's 500,000 times more luminous than the Sun. It's located in the Cassiopeia constellation.

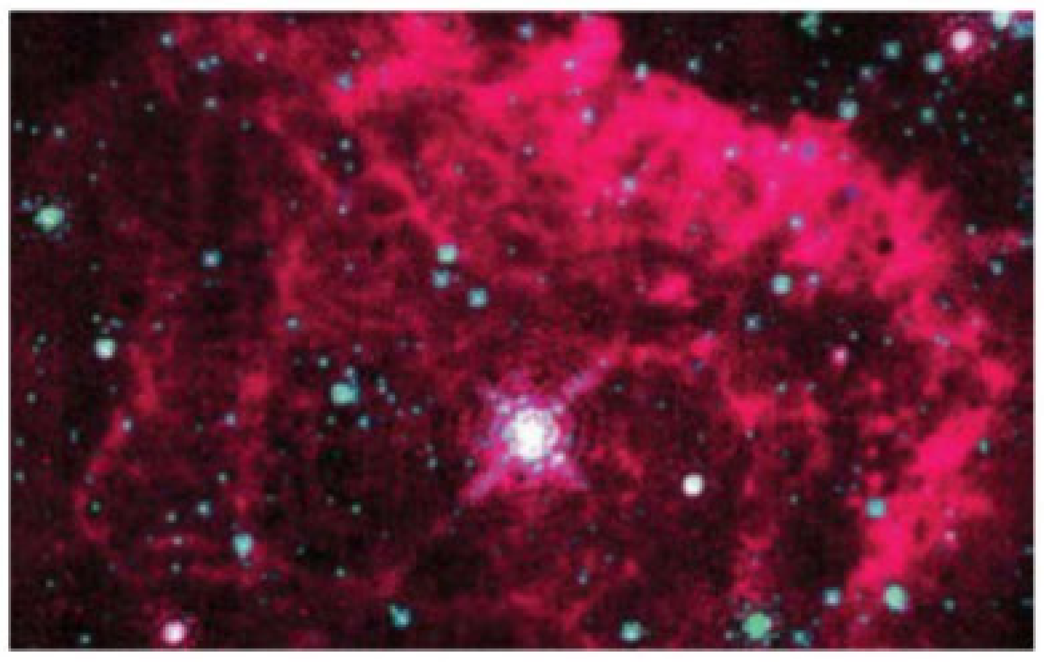
Milky Way hypernova



In April 2013, a JAXA (Japanese Aerospace Exploration Agency) experiment aboard the ISS revealed evidence of a hypernova remnant - the first to be found in our the Milky Way. The explosion is estimated to have been more than 100 times bigger than the average supernova and likely took place between two and three million years ago. At the time, only two remnants of hypernova and eight hypernova had been discovered outside our galaxy, but finding them is difficult because they look much like supernovae.

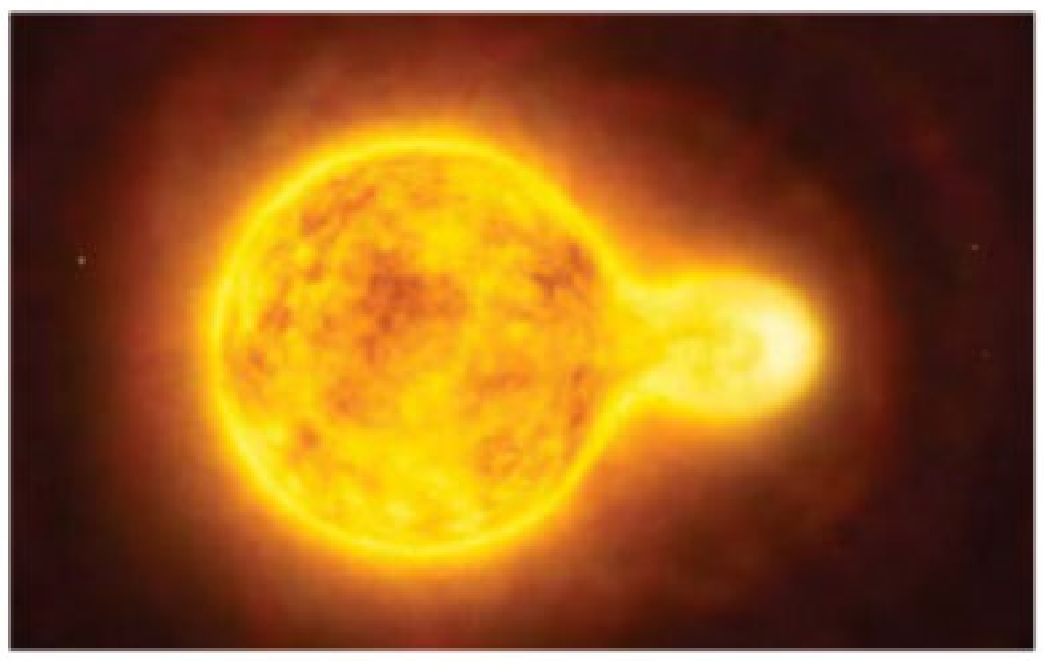


Pistol star



A blue hypergiant in Sagittarius, the Pistol star (V4647 Sgr) gets its nickname from the nebula of the same name, which it illuminates. This is a massive young star of 80 to 150 solar masses.

HR 5171 A



This binary star system, also dubbed the Peanut star, is a yellow hypergiant and one of the largest found so far. The two stars are so close that they're believed to be completely merged with each other.

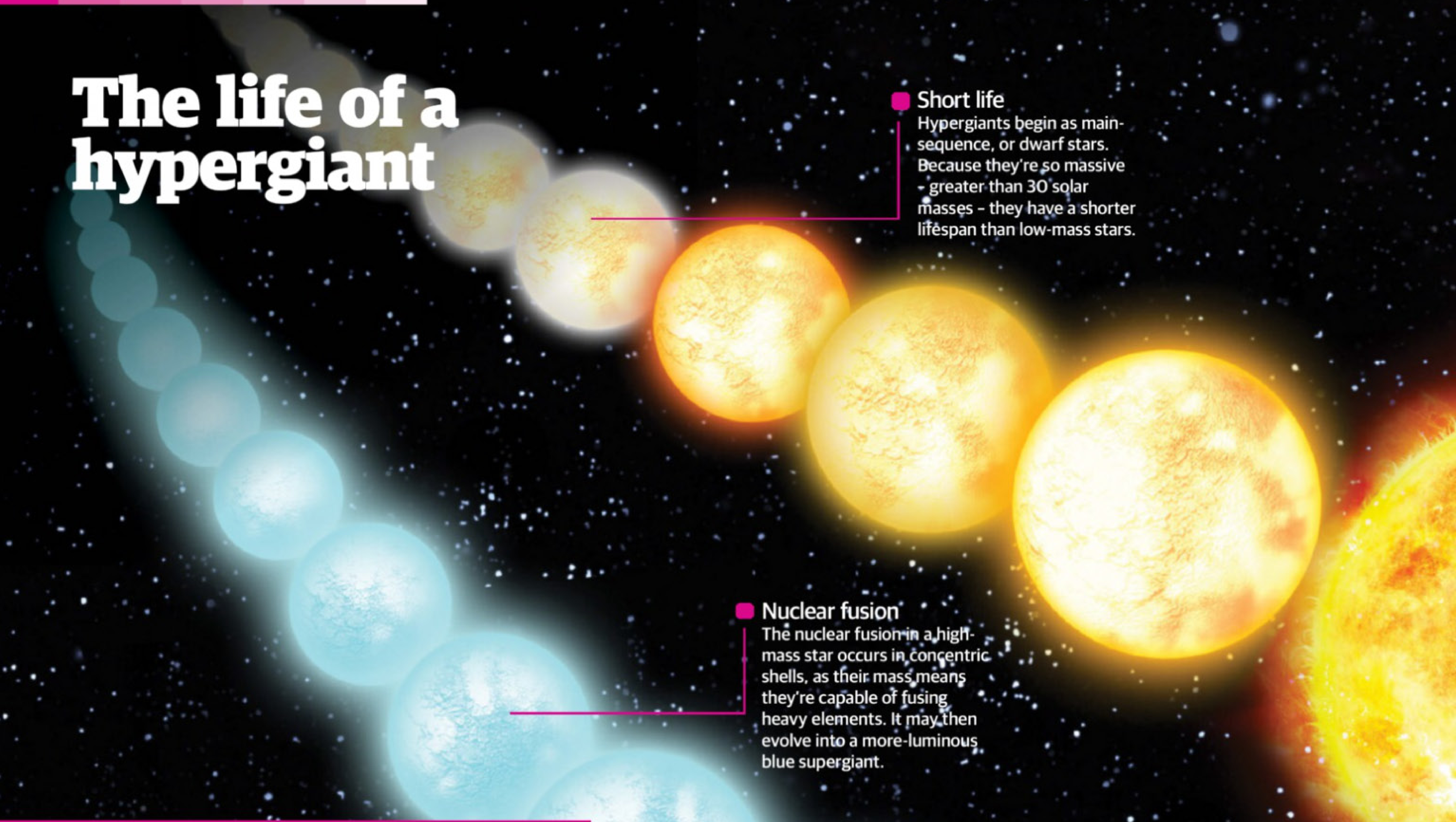
Zeta^1 Scorpii

This blue hypergiant is located in the Scorpius constellation and is one of the most luminous stars in the galaxy. It's estimated to be 850,000 times more luminous than the Sun.

Delta Canis Majoris

Located in the constellation Canis Major, Delta Canis Majoris is a yellow-white hypergiant. Due to its stability, astronomers often use its spectrum as an anchor point to classify other stars.

The life of a hypergiant



Short life

Hypergiants begin as main-sequence, or dwarf stars. Because they're so massive – greater than 30 solar masses – they have a shorter lifespan than low-mass stars.

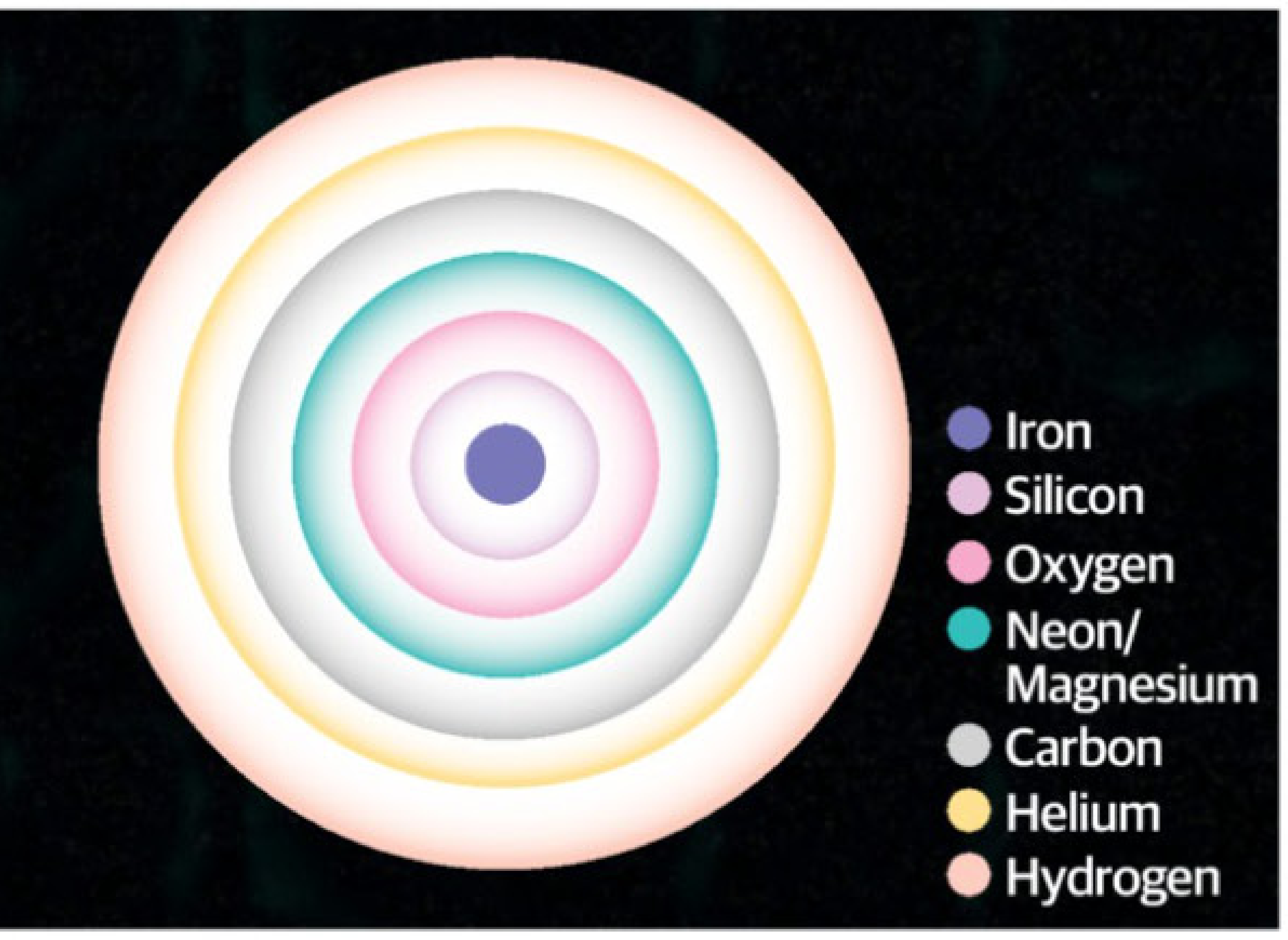
Nuclear fusion

The nuclear fusion in a high-mass star occurs in concentric shells, as their mass means they're capable of fusing heavy elements. It may then evolve into a more-luminous blue supergiant.

Quick burn

During its brief lifespan, a massive star rapidly burns through its fuel. Once the hydrogen is consumed, the star evolves away from the main sequence and its next steps depend on how massive it is.

From Shell to Supernova



This not-to-scale diagram illustrates the nuclear fusion cycle of a massive star. During a massive star's lifetime on the main sequence, it fuses elements in a series of concentric shells. Hydrogen, helium, carbon, neon/magnesium, oxygen and silicon burn inside the star under pressure and high temperatures. As each layer fuses, by-products from the process build up the shell bellow. The fusion of silicon results in a build-up of iron at the core of the star. Eventually the core can no longer sustain its own mass, reaching a point called the Chandrasekhar limit. It collapses, causing a violent explosion called a supernova.

Final stages
Towards the end of its life, the star can cool into a red hypergiant, or go back and forth between blue and a red supergiants.
Massive explosion
Once a high-mass star fuses silicon, iron builds up in its core and the star cannot support the mass. Once the core collapses, the hypergiant goes supernova. The type of supernova depends on how much mass the star is left with before it explodes.
Neutron Star
In some cases, the hypergiant supernova collapses into an incredibly dense neutron star.
Black hole
This is thought to be the chaotic result of a particularly massive supernova event.

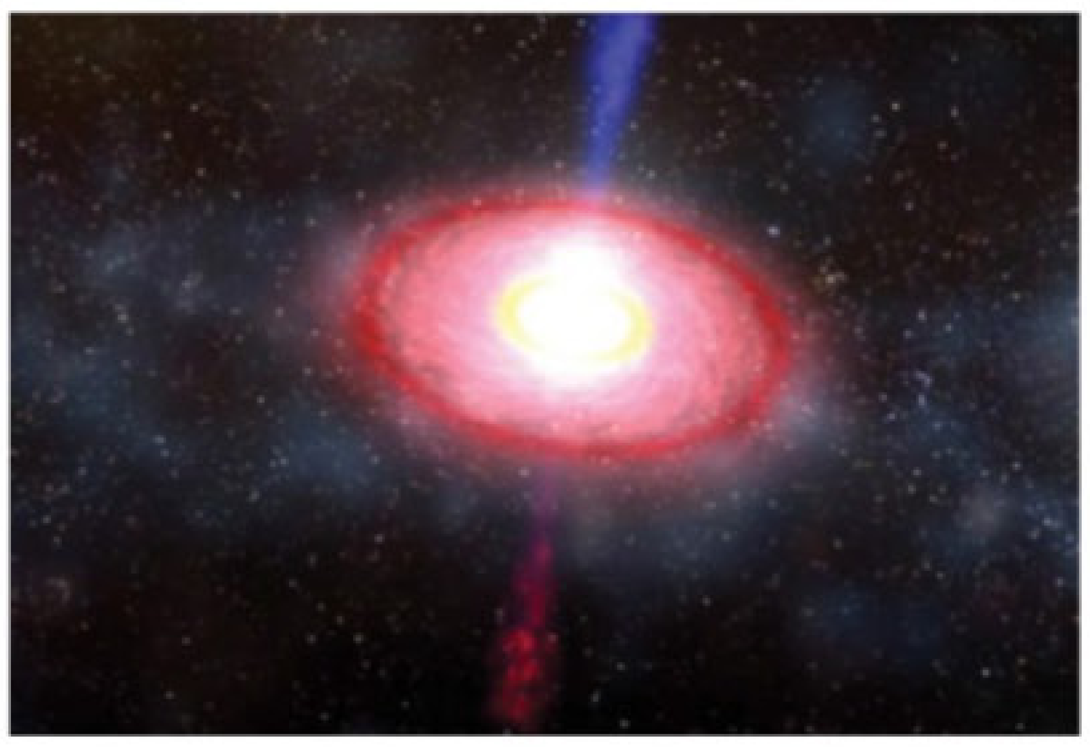
hidden behind the galactic bulge, or some could look like low-mass evolved stars (it's hard to measure the distance to a star and a nearby low-mass evolved star could look like a distant massive evolved star)."

Yellow hypergiants fall into one of two general categories – most of them are highly luminous and variable, believed to have evolved from red and on their way to becoming blue supergiants. The rest of the yellow hypergiants in our galaxy are likely evolving into red supergiants. These stars are more stable, although not as luminous, as the others. One of the brightest yellow hypergiants, HD 33579, is rare because it's believed to be evolving from being a blue hypergiant to a red hypergiant – currently it's called a white/yellow hypergiant.

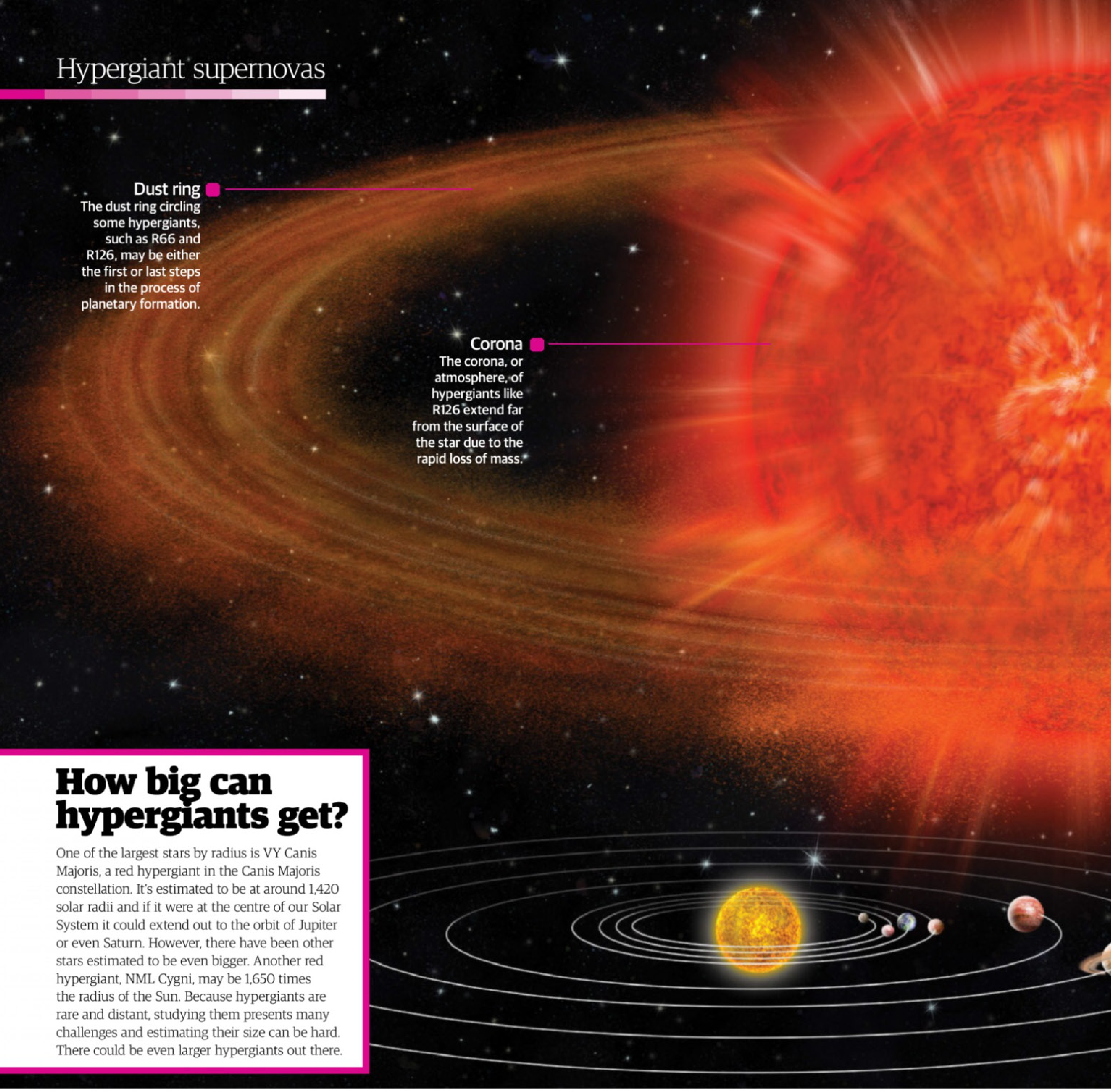
In March 2014, an international team of astronomers announced they had identified the largest yellow hypergiant known so far. HR 5171 A is a binary system located in the Centaurus constellation (and also known as HD 119796, HIP 67261 and V766 Centauri). It's a million times more luminous and about 40 times the mass of the Sun, while its radius is also over 1,300 times larger.

HR 5171 A has since been dubbed the Peanut star because of its peculiar shape, with a smaller secondary star in orbit around the primary. The secondary star has a solar radius of 400 and a mass that's six times the Sun's. Discovering that HR 5171 A was a binary star system surprised astronomers. "These stars are important as we still do not know exactly what happens before a star becomes a supernova, and the hypergiants are bright, so are excellently suited to study that," Oudmaijer explains. "The shock of HR 5171A was that it is a binary star,

Gamma ray bursts



Gamma ray bursts are among the brightest events in the known universe – bright flashes caused by intense beams of gamma radiation that are released during high-energy explosions. Supernovas, the most likely end for hypergiants, are some common sources of gamma ray bursts. "Recently people found some hypernovae to be associated with gamma ray bursts," Oudmaijer says. "This provided the first link between GRBs and stars." Gamma ray bursts can be long or short; the longer-duration bursts last more than 30 seconds and are the ones associated with the supernovas of massive stars like hypergiants.



Dust ring
The dust ring circling some hypergiants, such as R66 and R126, may be either the first or last steps in the process of planetary formation.

Corona
The corona, or atmosphere, of hypergiants like R126 extend far from the surface of the star due to the rapid loss of mass.

How big can hypergiants get?

One of the largest stars by radius is VY Canis Majoris, a red hypergiant in the Canis Majoris constellation. It's estimated to be at around 1,420 solar radii and if it were at the centre of our Solar System it could extend out to the orbit of Jupiter or even Saturn. However, there have been other stars estimated to be even bigger. Another red hypergiant, NML Cygni, may be 1,650 times the radius of the Sun. Because hypergiants are rare and distant, studying them presents many challenges and estimating their size can be hard. There could be even larger hypergiants out there.

which we did not anticipate at all. In a way it's back to the drawing board!"

Studying hypergiants is difficult because of their rarity, distance and sometimes their angular diameters. Some hypergiants are visible to the naked eye, but others end up surrounded in a cloud of dust and gas called a nebula – the by-product of their heavy mass loss. This makes it difficult for scientists to observe them visually, but infrared surveys can unveil much more. The identification of HR 5171 A's size was the result of more than half a century of observations. It was also observed using the European Southern Observatory's VLT (Very Large Telescope) Interferometer.

According to Lagadec, HR 5171 A is "too small to be resolved by even the largest telescope on Earth. We had to use a technique called interferometry that enables us to use two telescopes and have a kind of super-angular resolution, equivalent to the distance between the telescopes (the resolution of a telescope depends on its diameter and we can hardly build telescopes larger than ten metres [33 feet])". Interferometry combines light collected from multiple individual telescopes, to basically create the equivalent of one giant telescope.

Lagadec says that one of the biggest misconceptions about massive stars is they "take more time to evolve than low-mass stars. But this is the opposite. The lifetime of a star like the Sun is around ten billion years, while a star of 30 solar masses will live for only a few million years". Hypergiants have a lot of fuel, but they burn through it very quickly in comparison with less-massive stars. In other words, they live fast and die young.

But do they go out with a bang, or with a whimper? It depends on the star. The end of a hypergiant can go a couple of different ways. It can shed all of its outer layers and become a Wolf-Rayet star – a special type of incredibly hot, highly evolved, massive star. It can be the next stage for a blue or a red hypergiant, while more-massive, red supergiants may progress to hotter temperatures as they expel

Core
Once the nuclear fusion is complete in most hypergiants, their iron cores may collapse and lead to a supernova.

Our Solar System
This diagram shows that the massive dust ring around the star gives a total diameter that rivals the orbit of the dwarf planet Pluto.

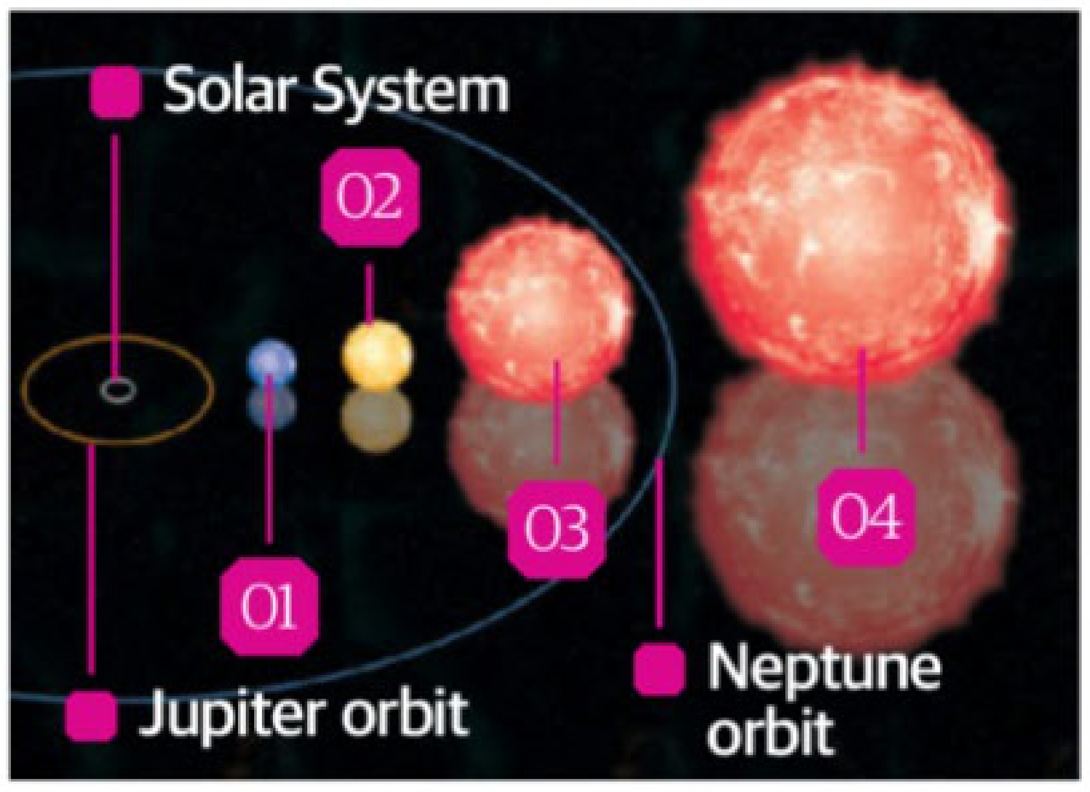
Profile of a hypergiant

Name: R126

Location: Large Magellanic Cloud
Type: Blue hypergiant
Diameter: 160 times the Sun's
Mass: 70 solar masses

Also known as HD 37974, R126 is one of two stars found in the Large Magellanic Cloud. It's extremely hot and luminous and is encircled by a large disk of dust thought to be regions of planetary formation.

Its discovery was surprising to astronomers, because it was previously thought that a hypergiant could not have planetary formation in their dust rings. They are supposed to have forceful interstellar winds that would prevent this from happening. The disk likely has ten times more mass than the Kuiper Belt.



1 – The Pistol star
2 – Rho Cassiopeiae
3 – Betelgeuse
4 – VY Canis Majoris

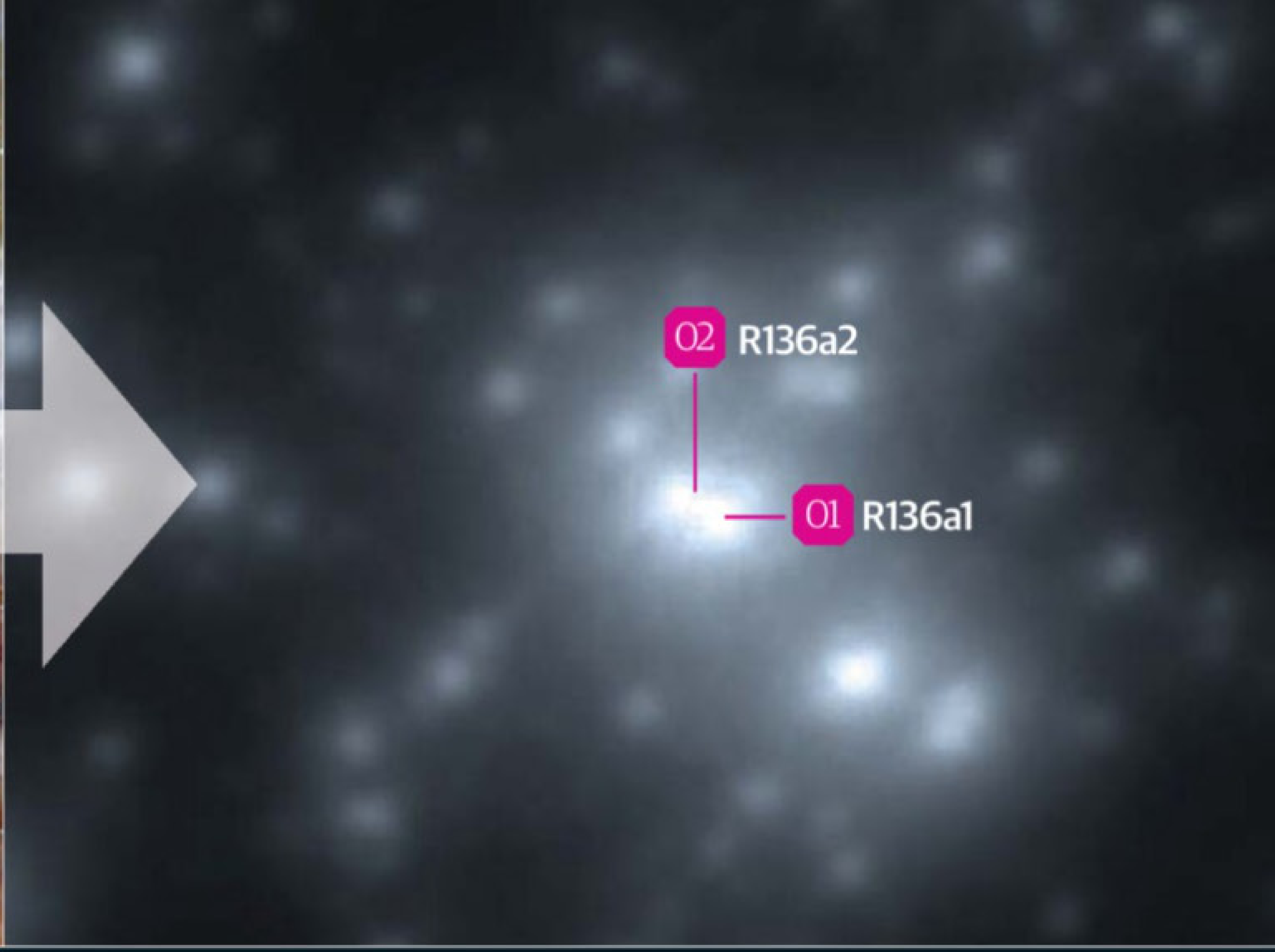
> "A star of 30 solar masses will live for only a few million years" **Eric Lagadec**

their atmospheres. Some explode while at the yellow hypergiant or LBV stage. A high-mass red hypergiant might go supernova right away, or go back to being a blue hypergiant as it heats up again. Some LBVs or yellow hypergiants may also go supernova.

A supernova occurs after the core of a massive star collapses, forcing the star's material – gas and dust – into the interstellar medium at about ten per cent the speed of light. Lagadec states that "this gas and dust is rich in elements that the star has created by nuclear fusion during its life. This is important to enrich the interstellar medium in heavy elements that will then be used to form new stars". The force of the explosion causes a burst of radiation that can provide more energy than the Sun during its lifetime, while the shell of gas and dust remaining is called a supernova remnant. Most supernovae come from the iron core collapses of supergiant or hypergiant stars.

There are also especially energetic supernovae called hypernovae, but not all hypergiants have hypernovae. A hypernova is defined as a supernova that explodes with a much greater amount of energy than average and may also be called superluminous supernovae. The term hypernova is somewhat recent, and were first suggested as a possible connection between gamma ray bursts and the supernovae of young, very massive stars. Gamma ray bursts are brilliant flashes of gamma rays and are some of the brightest events in the universe, but their origins were uncertain until recently. Now we know that at least some of the time the longer-lasting gamma ray bursts come from hypernovas. So some of the largest stars have among the biggest, flashiest and most-explosive ends. It's only fitting.

Future supernovas



1. R136a1
Solar masses: 265
Age: ≤ 2,000,000 years
Wolf-Rayet stars are extremely hot, massive stars that are rapidly losing mass due to a strong stellar wind. R136a1 has a luminosity estimated at around 10 million times greater than our Sun. It's one of the most massive stars in our universe and because it's so large it may go hypernova at the end of its lifetime.

2. R136a2
Solar masses: 200
Age: ≤ 2,000,000 years
Like its neighbour R136a1, R136a2 is a Wolf-Rayet star approximately six million times the luminosity of the Sun. Its fate depends on how much mass it has lost by the time its core collapses. R136a2 could end up going hypernova if it has a mass above 150 solar masses. Lower than that and it's more likely to be a supernova.

3. Eta Carinae
Solar masses: 120 (primary)
Age: ~3,000,000 years
Eta Carinae is located in the Carina constellation and is a binary star system. The primary is a luminous blue variable (LBV) and the star orbiting it is thought to be a supergiant of about 30 masses. There's a thick red nebula, or interstellar cloud of gas, obscuring our view. Because Eta Carinae is relatively close some astronomers think that when it goes supernova it may affect Earth.

4. VFTS 682
Solar masses: 150
Age: < 3 million years
Yes, VFTS 682 is another Wolf-Rayet star and has given us some stunning imagery. The star is more than 3 million times more luminous than our Sun and is found near the Tarantula nebula in the Large Magellanic Cloud – a very active star-forming region.

5. WR 102ka
Solar masses: up to 200
Age: < 3 million years
Another Wolf-Rayet star, WR 102ka may be the most luminous star in the Milky Way. It is also called the Peony star due to the shape of the nebula that surrounds it – one that likely formed from the mass lost due to fierce interstellar wind as well as small eruptions from the star. It's currently estimated that the Peony star will turn supernova within at least the next few million years.

Biggest hypernova ever

In 2007 the Nearby Supernova Factory based at the U.S. Department of Energy's Lawrence Berkeley National Laboratory found a supernova that was the very first of its kind – a pair-instability supernova. Further research by a team of astronomers revealed that SN 2007bi was not only one of the brightest supernova seen so far, it was also one of the most energetic and longest lasting. SN 2007bi is located in the dwarf galaxy Anon J131920+0855 in the Virgo constellation, and its precursor star was likely the kind that existed at the beginning of the universe. This is a giant star at least 200 times the mass of our Sun containing hydrogen and helium.

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10 AMAZING FACTS ABOUT
The Oort Cloud

The cloud is two light years wide

The sphere of this icy cloud is thought to surround the Sun at a distance of up to 50,000 AU, making its total diameter nearly two light years. Its outer edge is nearly a quarter of the distance from the Sun to its closest stellar neighbour, Proxima Centauri.

Comet Hale-Bopp was born here

Whereas short-term comets with orbital periods of up to 200 years, like Halley's, came from the Kuiper Belt, 1997's stunning long-period comet Hale-Bopp probably coalesced from the icy material that makes up the Oort Cloud.

Trillions of big icy bodies orbit here

Not including the countless smaller particles, there are several trillion icy objects, each with a diameter of over a kilometre (0.6 miles), making up the Oort Cloud. Though its total mass is hard to determine, it's thought to be around five times that of the Earth.

It's made of poisonous material

The Oort Cloud is made up of organic ices including water, methane and ethane. It also houses carbon monoxide and hydrogen cyanide, both of which can be deadly as gases in enclosed spaces. Ironically hydrogen cyanide is also thought to be a precursor to the compounds that played a role in the origins of life on Earth.

The temperature is extremely low

Even the closest heat source of any consequence – the Sun – is thousands of AU away from outer region of the Oort Cloud. Because of this, the temperature here is nearly absolute zero. Sedna, a dwarf planet found in the Oort Cloud, is the coldest object in the Solar System with a surface temperature of -240 degrees Celsius (-400 Fahrenheit).

It was part of the inner Solar System

When the Solar System was forming 4.5 billion years ago, the Oort Cloud was gradually coalescing over the span of the inner Solar System. It's thought that as the gas giants moved in the outer Solar System, the objects that made up the Oort Cloud were flung out to their current orbit.

It would take over 30 years to reach it

It's technically part of the Solar System, but despite this it would still take the latest spacecraft technology 30 years to travel up to 750 billion kilometres (466 billion miles) to reach its inner edge. Currently an ideal craft for that purpose would be a solar sail.

Dwarf planets have been found in it

Objects of around 450 kilometres (280 miles) in diameter have been discovered in the Oort Cloud within the last ten years. One of them, Sedna, has an extreme orbital period of 11,400 years that takes it from around 76 AU to 1,000 AU away from the Sun.

The Solar System ends here

It's a common misconception that the orbits of the outer planets and the dwarf planet Pluto mark the edge of the Solar System, when in fact the gravitational influence of the Sun extends much further into space. This is evidenced by the hold our star still has on the far-away objects within the Oort Cloud that lie many times that distance away, if only at a greatly reduced strength.

It might not exist

The sphere of the Oort Cloud was hypothesised to exist around our Solar System by Dutch astronomer Jan Oort (after whom it was named) in 1950. Since then, astronomers have tracked objects moving through and within it but are yet to make direct observations of the Cloud itself. ●

This huge, freezing and poisonous cloud is thought to mark the furthest extent of the Solar System

© Alamy

Explore the Milky Way

The Spitzer Space Telescope takes a panoramic image through the plane of our galaxy

In five years' time the European Space Agency team behind Gaia will be able compile enough data, from the billion stars surveyed, to determine all their distances and motions. From this they will then be able to create a three-dimensional map of the Milky Way. While not wanting to detract from a clearly incredible achievement, five years is a long time to wait – especially when there's a surveyor already in orbit that has achieved a similar feat in two dimensions, to what Gaia aims to achieve in three.

The Spitzer Space Telescope was launched in 2003 with the primary mission of observing the universe in infrared. It used liquid-helium cryogenic coolant to keep its instruments at a temperature a fraction above absolute zero (-273.15 Celsius or -459.67 Fahrenheit), which was necessary for the telescope to pick out some of the coolest celestial objects in the universe. The coolant ran dry in May 2009, meaning these instruments no longer worked and Spitzer began running at -240 Celsius (-400 Fahrenheit).

Some years prior to the Warm Mission, Spitzer began taking what would amount to over two million infrared images through the plane of the Milky Way. This would be dubbed the GLIMPSE (Galactic Legacy Infrared Mid-Plane Survey Extraordinaire) project. These were combined with data from other surveys and stitched together to create an impressive panorama of the Milky Way.

An infrared view of our galaxy is desirable because light in the visible portion of the electromagnetic spectrum is eventually blocked by dust at an average of about 1,000 light years away, giving us a view of a measly five per cent of the galaxy. Infrared light passes easily through this dust to give us almost a complete view of the Milky Way and its many stars.

From our position, 26,000 light years from the galactic core, GLIMPSE shows us the shape of the galaxy and the position of its spiral arms. The brightest and most vivid section of the panorama marks the centre of the Milky Way, Sagittarius A, a concentrated source of radiation and the thickest point through the galactic plane that Spitzer took its images from. Conversely, the darkest sections are our galactic backwater, where the telescope is looking directly out to the furthest fringes of the galaxy. Here, much fainter and lower-mass stars have been detected that haven't been picked up before. The GLIMPSE project has shown that the Milky Way is slightly bigger than thought and is pocked with bubble-like cavities created by massive stars with powerful stellar winds.

Spitzer's three instruments cover the infrared portion of the spectrum from 160 micrometres to the shortest wavelength sensitivity of 3.6 micrometres. This includes the Infrared Array Camera (IRAC), which has been snapping away with its four modules operating at different wavelengths to help create this iridescent panorama.

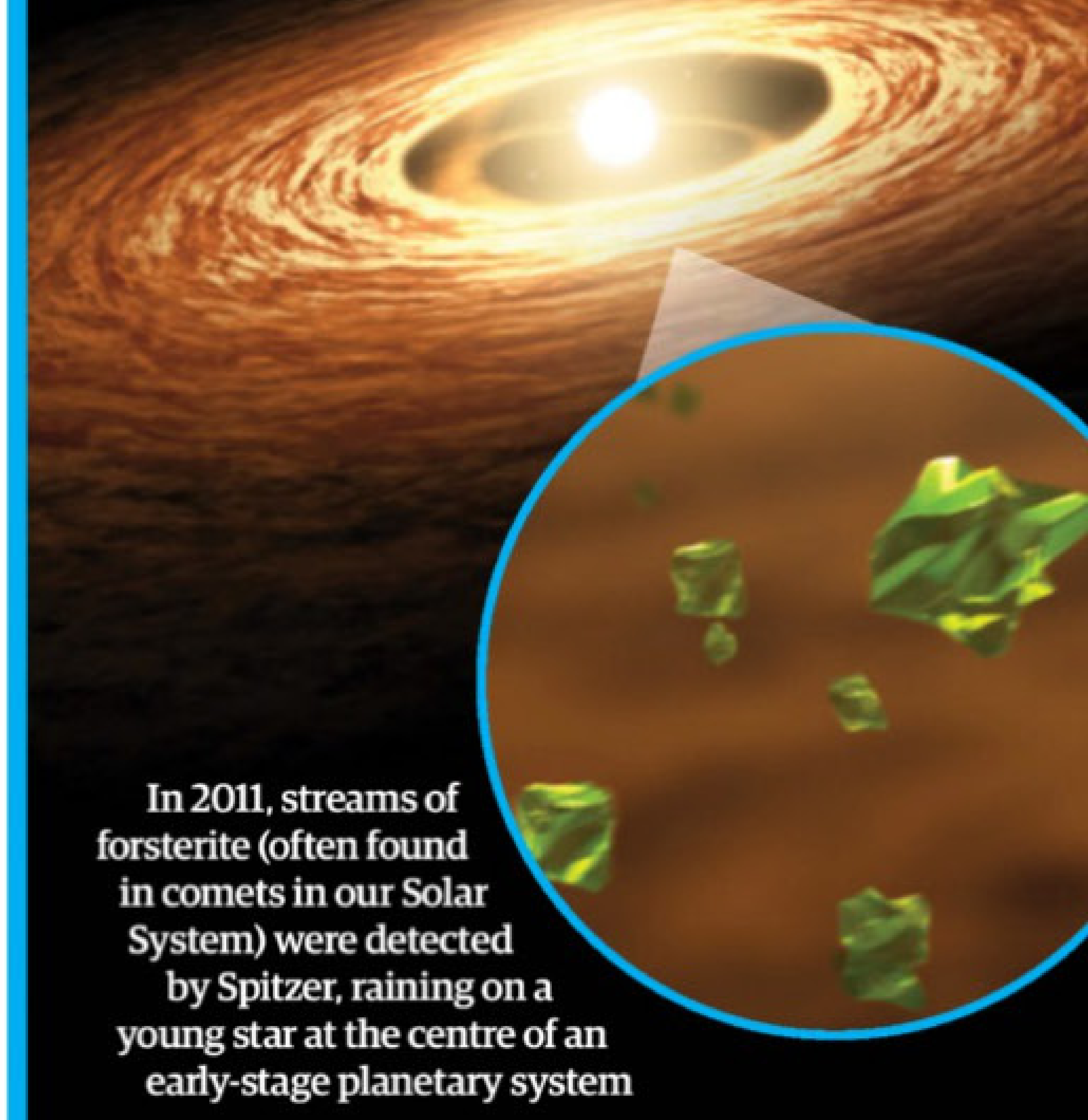
The different colours in the panorama are the various wavelengths of infrared light picked up by IRAC's cameras and MIPS (Multiband Imaging Photometer for Spitzer) imager, at 3.6, 4.5, and 24 micrometres. The coolest regions captured by Spitzer are actually red and were picked up by the camera operating at the longer wavelength of 24 micrometres, marking cloud regions of warm interstellar dust. At a higher wavelength, organic compounds called polycyclic aromatic hydrocarbons are excited by radiation from massive stars and show up in green. Blue and white are the hottest regions, usually thermal emissions direct from mature stars.

The masses of data, in addition to this GLIMPSE panorama, is still being pored over by scientists and will continue to be for years. The data from the image has proven a reliable way to verify astronomical findings and discover new objects.

Read on to see the full panorama of the Milky Way, as pictured by the Spitzer Space Telescope

> "Spitzer began taking what would amount to over two million infrared images"

What has the GLIMPSE survey found?



In 2011, streams of forsterite (often found in comets in our Solar System) were detected by Spitzer, raining on a young star at the centre of an early-stage planetary system

Apart from giving us a better idea of the shape and size of the Milky Way, scientists have discovered masses of new celestial features by scrutinising the data from Spitzer's GLIMPSE survey. This includes over 20,000 red sources, three quarters of which are stars in the making and a quarter of which are evolved stars. Over 500 variable stars have been discovered, 591 polycyclic aromatic hydrocarbon bubbles created by the stellar wind from massive stars and 59 new star clusters spotted. Spitzer's primary mission came to an end five years ago when its coolant ran out, but these figures are changing all the time as more data is processed.

GLIMPSE by numbers

2 gigapixels went into creating the full-size image.

46 sq m *is the area the full image would cover.*

50% of the galaxy is captured in the panorama.

100,000x size difference between the smallest and largest objects.

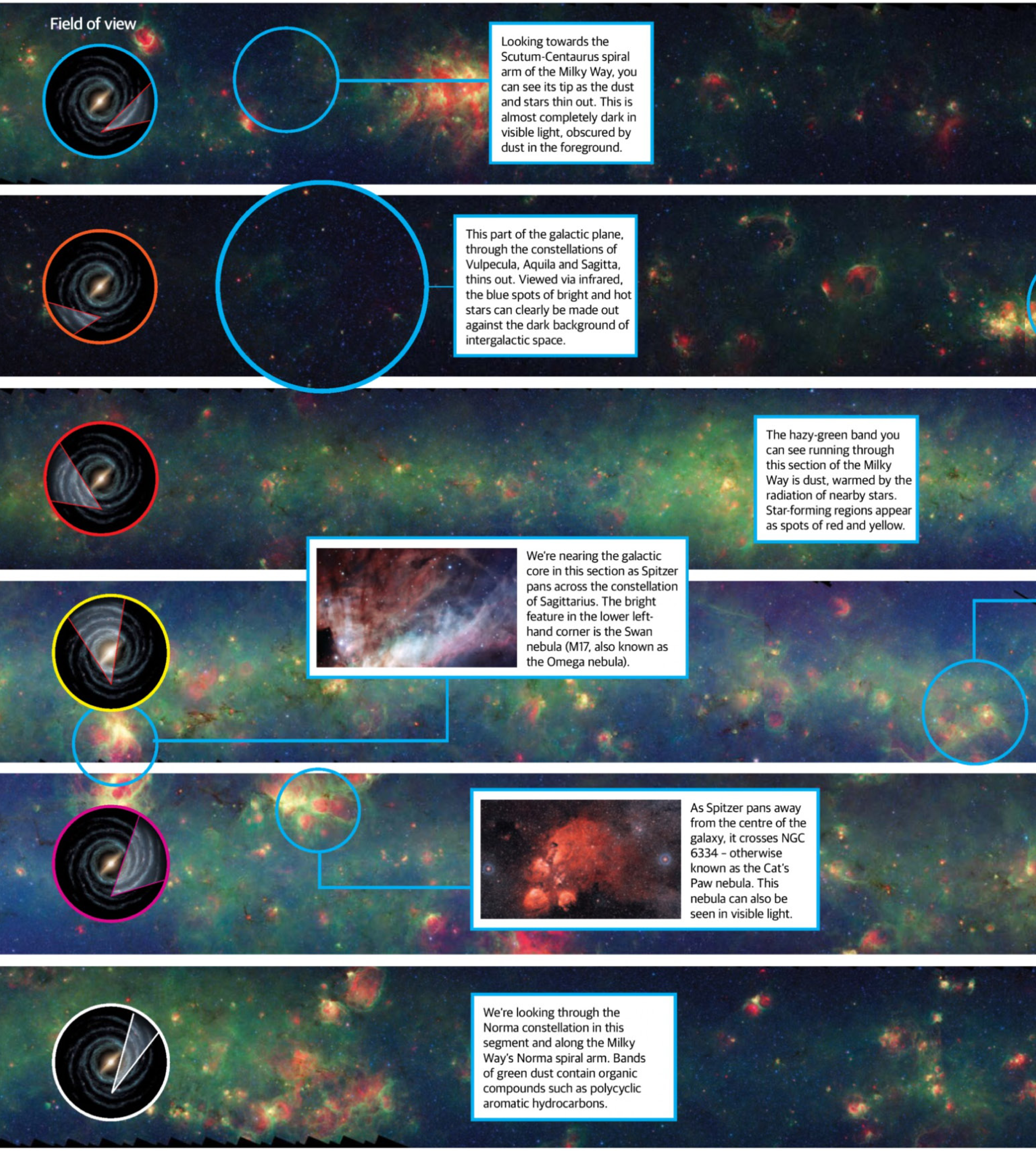
150 billion stars are captured in this image.

2 million infrared images created this result.

95% of the galaxy is hidden in visible light.

800,000 individual frames were stitched together to create the panorama.

100 million *stars catalogued as a result of the survey.*



Looking towards the Scutum-Centaurus spiral arm of the Milky Way, you can see its tip as the dust and stars thin out. This is almost completely dark in visible light, obscured by dust in the foreground.

This part of the galactic plane, through the constellations of Vulpecula, Aquila and Sagitta, thins out. Viewed via infrared, the blue spots of bright and hot stars can clearly be made out against the dark background of intergalactic space.

The hazy-green band you can see running through this section of the Milky Way is dust, warmed by the radiation of nearby stars. Star-forming regions appear as spots of red and yellow.

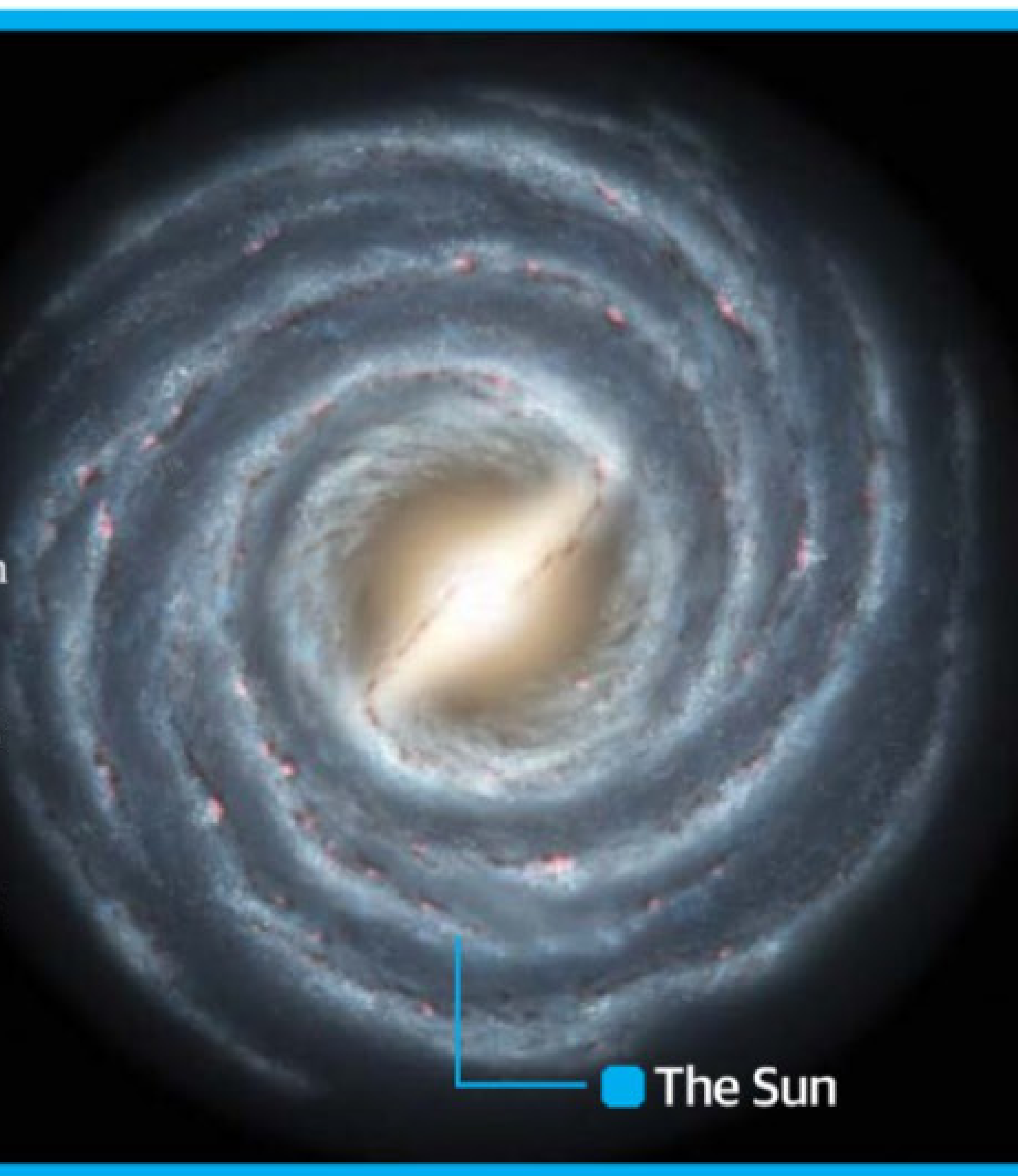
We're nearing the galactic core in this section as Spitzer pans across the constellation of Sagittarius. The bright feature in the lower left-hand corner is the Swan nebula (M17, also known as the Omega nebula).

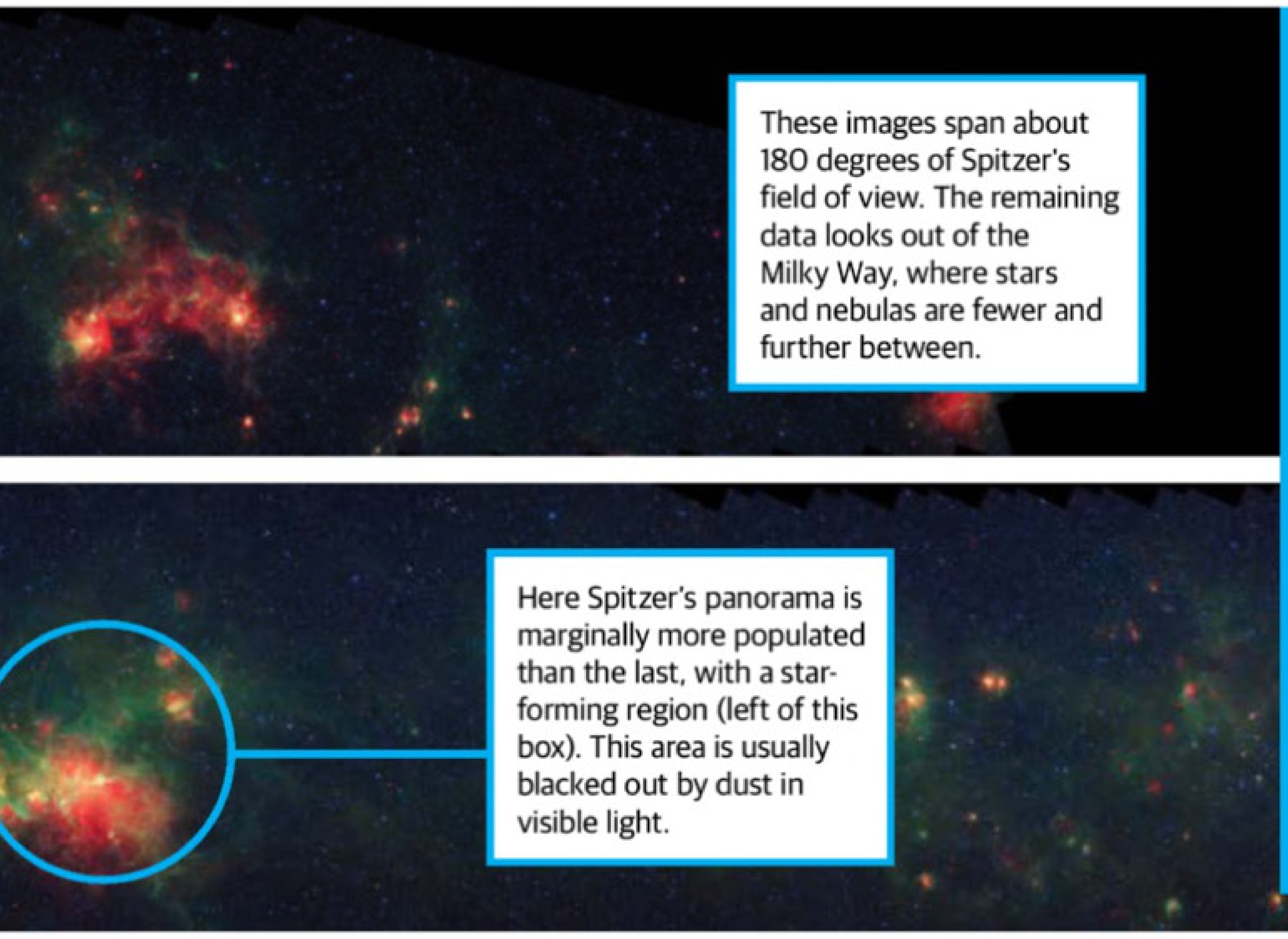
As Spitzer pans away from the centre of the galaxy, it crosses NGC 6334 – otherwise known as the Cat's Paw nebula. This nebula can also be seen in visible light.

We're looking through the Norma constellation in this segment and along the Milky Way's Norma spiral arm. Bands of green dust contain organic compounds such as polycyclic aromatic hydrocarbons.

What am I looking at?

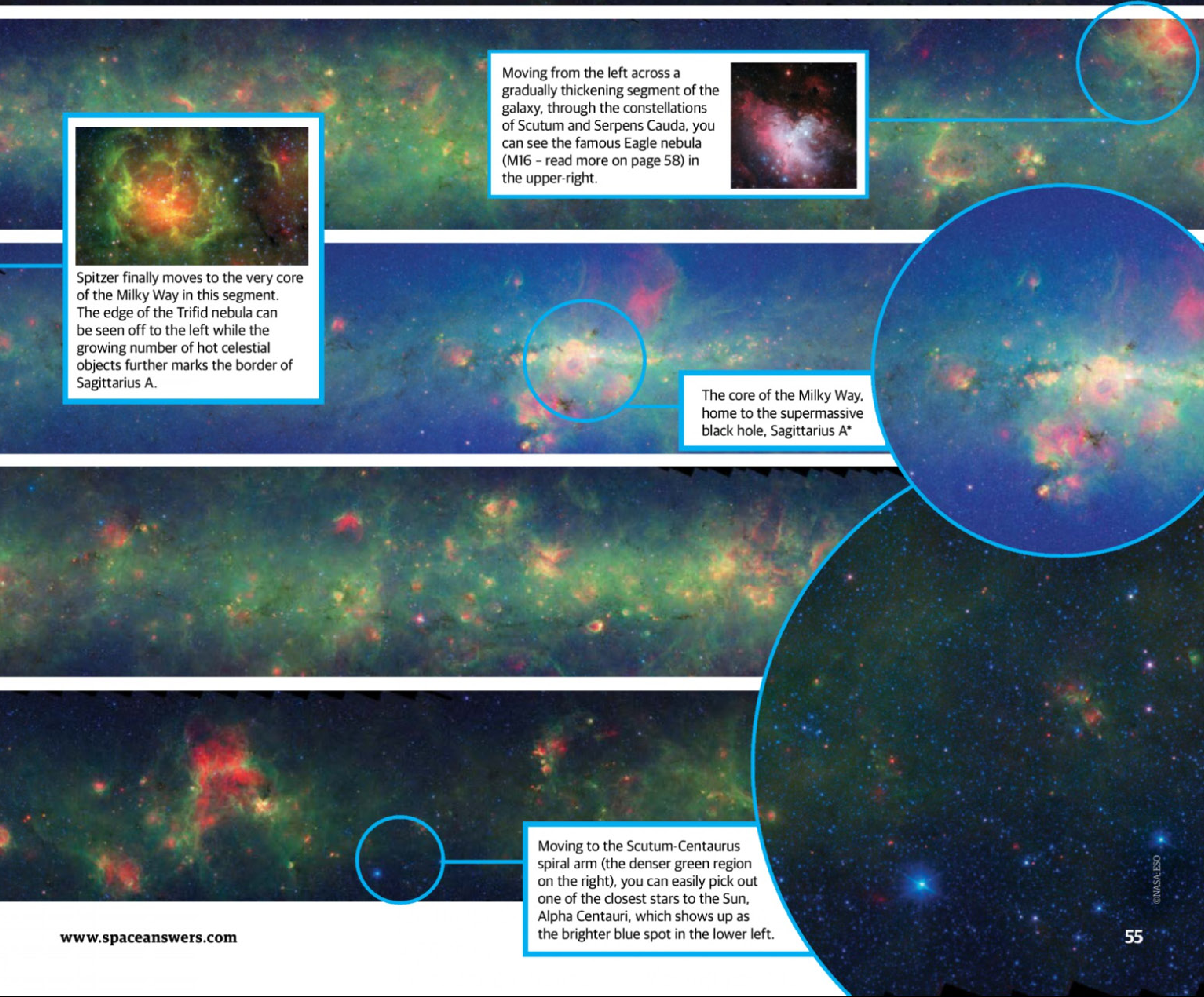
The Solar System occupies a tiny space about two thirds of the way out from the galactic core to the edge of the galaxy, while the shape of the Milky Way is a flat spiral with a bulbous centre. From its vantage point, trailing behind the Earth in heliocentric orbit at around 150 million kilometres (93 million miles) away, the Spitzer Space Telescope can see through the plane of the galaxy. By taking infrared images from various angles on its axis, the full galaxy is shown to be a long, mostly flat panorama that doesn't show the





These images span about 180 degrees of Spitzer's field of view. The remaining data looks out of the Milky Way, where stars and nebulas are fewer and further between.

Here Spitzer's panorama is marginally more populated than the last, with a star-forming region (left of this box). This area is usually blacked out by dust in visible light.



Moving from the left across a gradually thickening segment of the galaxy, through the constellations of Scutum and Serpens Cauda, you can see the famous Eagle nebula (M16 – read more on page 58) in the upper-right.

Spitzer finally moves to the very core of the Milky Way in this segment. The edge of the Trifid nebula can be seen off to the left while the growing number of hot celestial objects further marks the border of Sagittarius A.

The core of the Milky Way, home to the supermassive black hole, Sagittarius A*

Moving to the Scutum-Centaurus spiral arm (the denser green region on the right), you can easily pick out one of the closest stars to the Sun, Alpha Centauri, which shows up as the brighter blue spot in the lower left.

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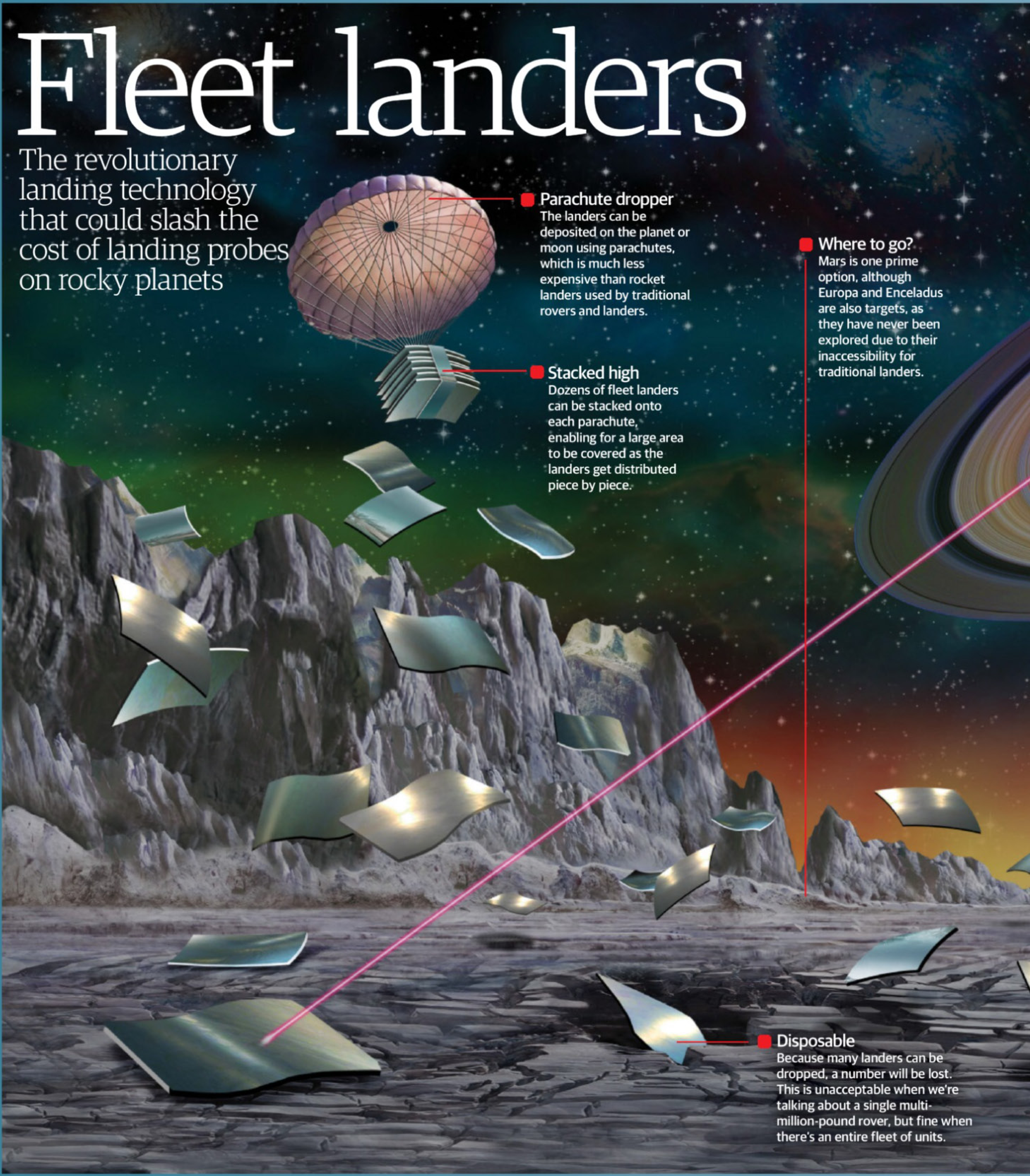
Fleet landers

The revolutionary landing technology that could slash the cost of landing probes on rocky planets

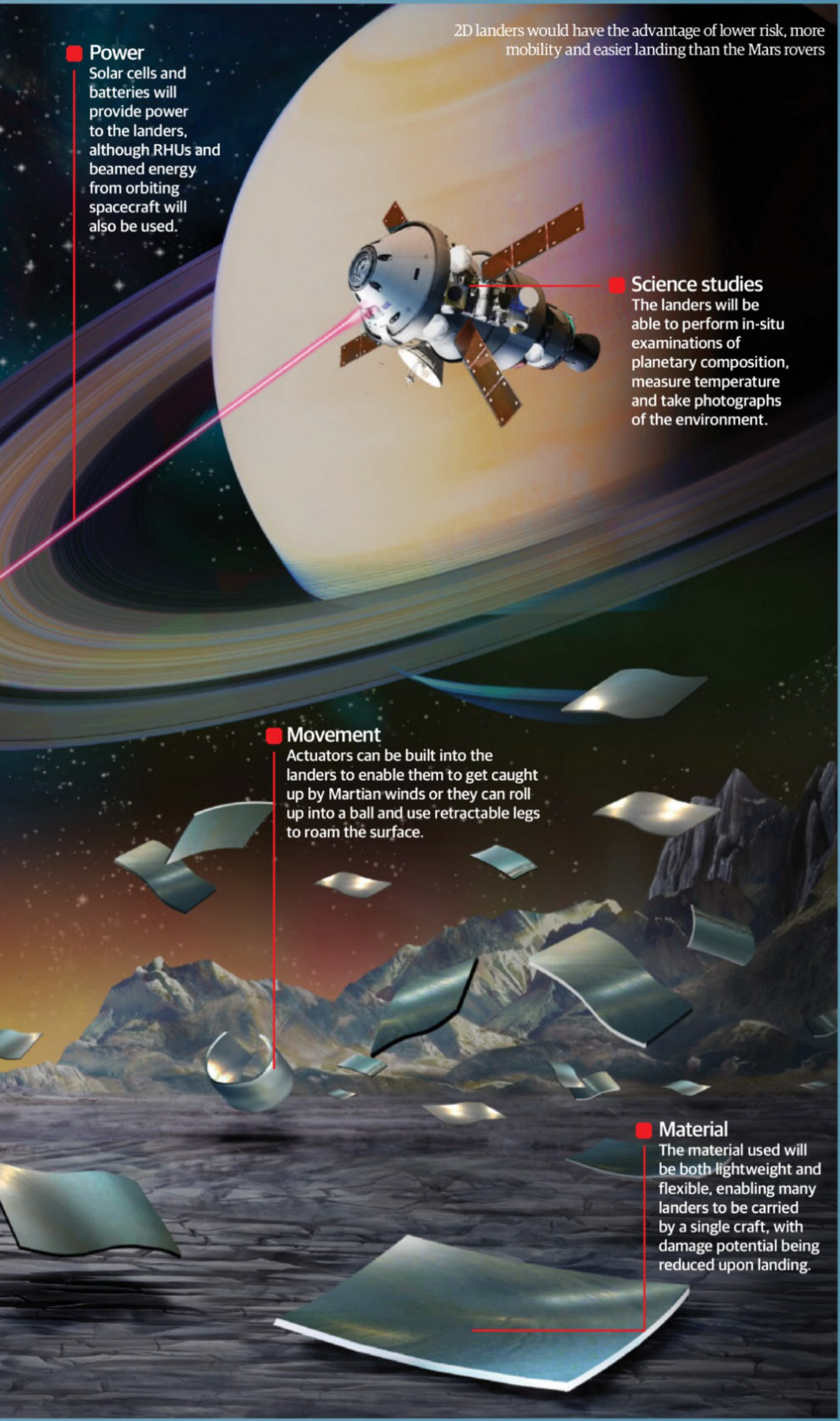


Parachute dropper
The landers can be deposited on the planet or moon using parachutes, which is much less expensive than rocket landers used by traditional rovers and landers.

Stacked high
Dozens of fleet landers can be stacked onto each parachute, enabling for a large area to be covered as the landers get distributed piece by piece.

Where to go?
Mars is one prime option, although Europa and Enceladus are also targets, as they have never been explored due to their inaccessibility for traditional landers.

Disposable
Because many landers can be dropped, a number will be lost. This is unacceptable when we're talking about a single multi-million-pound rover, but fine when there's an entire fleet of units.



2D landers would have the advantage of lower risk, more mobility and easier landing than the Mars rovers

Power
Solar cells and batteries will provide power to the landers, although RHUs and beamed energy from orbiting spacecraft will also be used.

Science studies
The landers will be able to perform in-situ examinations of planetary composition, measure temperature and take photographs of the environment.

Movement
Actuators can be built into the landers to enable them to get caught up by Martian winds or they can roll up into a ball and use retractable legs to roam the surface.

Material
The material used will be both lightweight and flexible, enabling many landers to be carried by a single craft, with damage potential being reduced upon landing.

One of the major problems of planetary exploration is how to land a probe safely on a planet. Landers and rovers need to touch down in a very particular, usually flat, area. The fact that the team only ever gets one attempt at it makes the process an extremely risky event, with disastrous and expensive repercussions following any kind of mistake during the nail-biting process.

Fleet landers, proposed by the Jet Propulsion Laboratory team at NASA, could make this moment of tension a thing of the past. The idea is to attach dozens of sheets to a parachute lander, which releases them above the planet or moon. These sheets then flutter down and spread over the surface. Because the sheets are flat and flexible, they'll settle anywhere. They also don't need to be carefully landed using expensive rockets, because dozens will land at a time, so there's a much higher chance of a successful landing.

The plan is for the one-metre- (3.3-foot-) square and one-centimetre- (0.4-inch-) thick landers to piggyback on spacecraft and be dropped on inhospitable bodies such as Mars, Europa, Enceladus and Titan. Rovers can have problems on the erratic surface of Mars, so would struggle in the extreme environment of Venus, while the geysers of Europa and Titan would also pose a risk to traditional ventures. None of these would be a problem for a fleet of two-dimensional surface landers, because if a few get lost or swallowed up, there are plenty of others that can take their place.

From here, they will be able to conduct experiments such as locating water, measuring pH levels, analysing dust particles and taking photographs. They will use super-thin technology implanted into the sheets to carry out these actions, such as wide-angle cameras, wireless transmitters, temperature, altitude and pressure sensors. They will gain their power from solar cells implanted into the sheet – thin batteries that store energy and Radioisotope Heater Units (RHUs), which provide energy via the heat created by the decay of plutonium-238. They could also be energised using a beam from the craft that dropped them as Europa, for example, is too far from the Sun to provide energy.

Actuators will be set into the sheets, lifting them up so they can either be blown along by Martian winds, or roll themselves into balls and negotiate the planet on tiny, retractable feet. This enables them to cover vast distances of the surface and map huge areas with wide-angle cameras. Enceladus will be a fascinating body to explore close up, due to the liquid oceans found underneath its surface. In-situ, wide-angle photographs could unlock many of the secrets hidden from conventional orbiters.

Although rovers and conventional landers will still play a vital role in space exploration, these landers are unsurprisingly an attractive proposition for research teams looking to create a low-cost, low-risk venture to distant worlds. They can perform many tasks required of bigger and more-expensive equipment and don't require the precision when landing. Just as tablets are steadily replacing desktop and laptop computers, these thin, flexible sheets with the ability to move on the breeze could very soon be replacing the cumbersome and pricey rovers and landers we know today. ●

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All About…

THE EAGLE NEBULA

The dark, dusty columns of the three Pillars of Creation extend into the hazy glow of the Eagle nebula, sculpted and illuminated by the intense radiation of a jewel box of blue and white stars

Written by Laura Mears

The Eagle nebula, M16, is found in Serpens, a unique two-part constellation. The head of the snake, Serpens Caput, is in the Northern Hemisphere pointing in the direction of Corona Borealis, while the tail, Serpens Cauda, is in the Southern Hemisphere, lying south of the bright star Altair in the constellation Aquila. The two parts of the serpent are separated by a second constellation, Ophiuchus, also known as the Serpent-Bearer.

Serpens is home to a variety of beautiful and unusual objects, from a diamond planet orbiting a pulsar that rotates 10,000 times every minute, to Seyfert's Sextet – a group of galaxies so close that they're gradually merging into one huge super galaxy.

The head of the serpent contains Messier 5, one of the oldest globular clusters in the Milky Way. The symmetrical star system measures 165 light years across and contains over 100,000 stars, most of which formed over 12 billion years ago, around seven billion years before the Solar System. The brightest stars have an apparent magnitude of 12.2 and on a good night the cluster can even be visible to the naked eye.

The northernmost part of the serpent's head is home to a near-perfect ring galaxy known as Hoag's Object. This galaxy isn't only a stunning example of the rare shape, measuring 100,000 light years across, but far in the distance between the core and the ring lies a second ring galaxy.

Serpens is also home to the Red Square nebula, one of the most complex, naturally occurring, yet symmetrical objects in the known universe. Hot stars at the centre of the nebula are thought to have expelled cones of gas at some point during their development, which when viewed in cross-section, as they are from the Earth, appear in the shape of an almost perfect square.

By far the most famous object in the Serpens constellation is the vast molecular dust cloud of the Eagle nebula, found within the serpent's tail. It's seen as a hazy, pinkish glow just to the north of an S-shaped collection of stars.

The Eagle nebula is a HII region – a cloud of glowing gas partially ionised by the ultraviolet radiation released by the bright young star cluster known as NGC 6611. The nebula evolved from a giant molecular cloud, which is a dense collection of dust and molecular hydrogen gas with an average temperature of just a few tens of degrees above absolute zero.

This molecular cloud is thought to have extended across the Sagittarius arm of the galaxy, before a series of shocks caused local regions to collapse in on themselves, accumulating matter under the force of their own increasing gravitational pull and eventually giving birth to energetic stars.

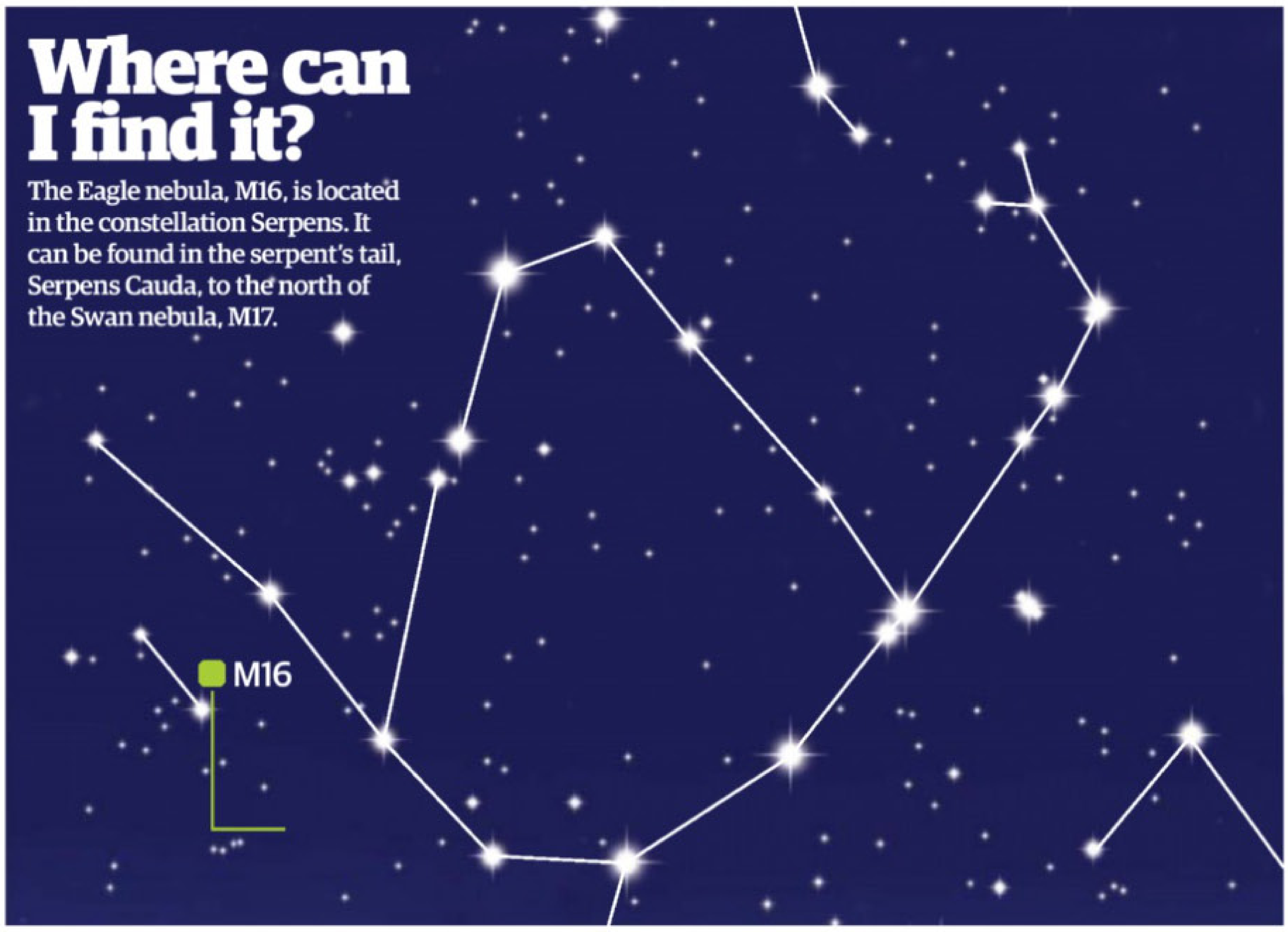
A thin wisp of molecular gas connects the Eagle nebula with the nearby Swan nebula, M17, and it's thought the two regions were originally formed from the same giant molecular cloud. There are two similar nebulae further along the Sagittarius arm of the galaxy that are also believed to belong to the same group: the Lagoon nebula M8 and the Trifid nebula M20.

The massive stars that power the Eagle nebula release huge quantities of ionising, ultraviolet radiation, which energises the gas in the surrounding molecular cloud, causing it to glow. The ionised material moves faster than the speed of sound and generates shock waves that tear through the unionised dust and gas, compressing more matter and leading to the formation of more stars.

The nebula is by now in the later stages of its evolution and the production of new stars has slowed as the open star cluster, NGC 6611, has driven the remaining dust and gas to the edges, forming the familiar shape of an eagle. Eventually radiation pressure from these new stars will cause the remainder of the nebula to disperse, leaving just the star cluster behind. ●

Where can I find it?

The Eagle nebula, M16, is located in the constellation Serpens. It can be found in the serpent's tail, Serpens Cauda, to the north of the Swan nebula, M17.



Dynamics of the Eagle nebula

Molecular cloud
The darker material of the Eagle nebula has yet to be ionised by radiation and is composed mainly of dust and molecular hydrogen gas. It's so cold that it emits no visible light at all.

Shock wave region
Supersonic gas from the HII region meets subsonic gas in the molecular cloud, forming a shock wave that triggers local collapse of dust and gas, leading to pockets of intense star formation.

North bay
The ionising radiation released by massive young stars has carved a bowl-shaped hollow in the north-eastern portion of the dust cloud.

Ionising stars
The material from the molecular cloud feed the growth of massive, energetic stars, which in turn generate shock waves that trigger star formations in other areas of the nebula.

Pillars
Pillars of molecular hydrogen and dust extend into the HII cavity, gradually eroding at the tips as they are bombarded by shock waves and radiation levels.

HII cavity
Massive, energetic stars generate enough ultraviolet radiation to ionise the surrounding gas, energising the molecules so much that they boil away into space, leaving behind a radiation-bathed cavity.

Not long for this world

Recent infrared images captured by the Spitzer Space Telescope in 2007 revealed an ominous cloud of hot dust surrounding the Pillars of Creation, similar to the dust found close to the remnants of a supernova. If predictions are right, this hot dust would be followed by a shock wave that will blast the Pillars of Creation far into space.

In fact, it's likely that this has already happened. Given the time it takes for light to travel from the Eagle nebula to the Earth, the images are around 7,000 years out of date. The shock wave that followed the hot dust in Spitzer's images would have torn through the pillars 6,000 years ago, stripping the gas and dust away from the newly forming stars.

The light from this cataclysmic event has yet to reach us, but the original supernova explosion would have been visible at some point over the last 1,000 to 2,000 years as a bright star in the sky and 1,000 years from now we should be able to watch the pillars begin to fall.

Inside the Eagle

New stars are forming within the caps of the nebula's swirling towers

The glow of the Eagle nebula is generated by the massive O- and B-type stars that populate its centre. Many times more massive than the Sun, these enormous stars burn hot and fast, ejecting ionising radiation and stellar wind into the heart of the nebula, sending shock waves through the cloud.

M16 is coming to the end of its star-forming lifetime and the remaining molecular cloud has been forced out to the edges, leaving the centre comparatively empty and bathed in ultraviolet radiation. However, There are still some pockets of star-forming activity left.

The largest stars are concentrated in the north-eastern corner of the nebula, where they have carved a semi-circular basin into the molecular cloud. The shock wave generated by these enormous stars is compressing the gas in the north bay, while sources of infrared light, that could be newly forming stars, are visible within the dust. There is also evidence of masers - water molecules in the vicinity of star-forming regions that absorb energy, emitting this out as microwaves.

To the south are the iconic Pillars of Creation, three distinctive lanes of dark dust and gas. These eerie stalagmites on the floor of the nebula have resisted erosion for far longer than the surrounding gasses, forming structures several light years tall. They are bordered on either side by older, cooler stars, which would once have showered the columns with radiation, sculpting them inwards towards the heart of the nebula. As these stars aged, the columns stretched out, reaching towards the cluster of massive stars in the north bay.

Most of the material along the lengths of the pillars has been stripped away, but the caps still contain pockets of denser gas and dust. As the radiation from the ionising stars reaches the tops of the pillars, the gas is boiled away in a process known as photoevaporation, leaving visible streamers twisting out from the surface of the pillar caps.

Beneath the outer gas layers, regions of denser gas start to become visible. Known as EGGs, or evaporating gas globules, these dense pockets are larger than the Solar System and are thought to be the precursors to protostars. When buried within

The Eagle's key features

1. Pillars of Creation
The emissions from the stars of the NGC 661 cluster shock, ionise and boil away the molecular gas cloud, sculpting these vast pillars.

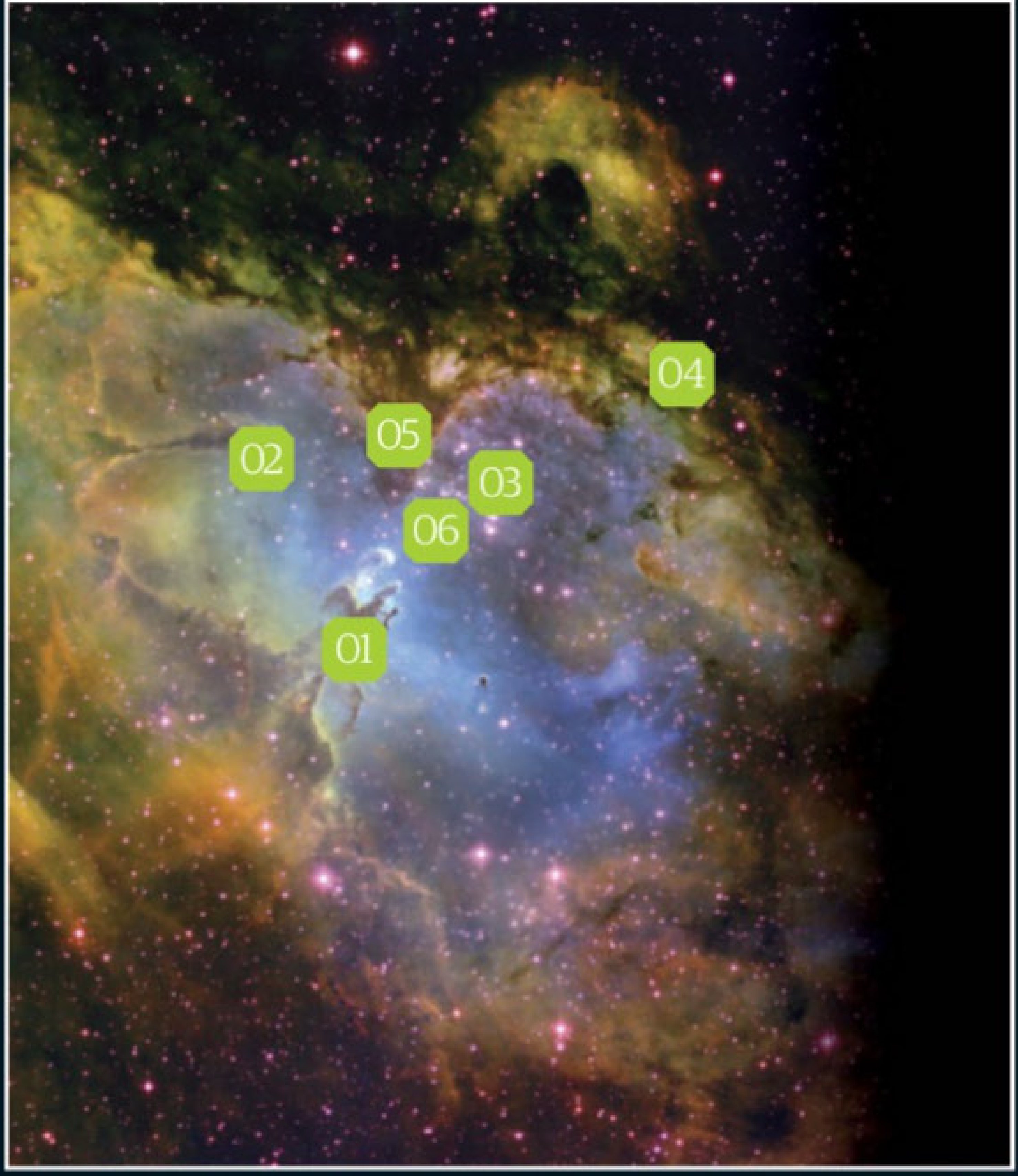
2. Column V
To the north-west of the pillars is another enormous column of gas. Measuring 9.5 light years in length, the column has a dense cap with an ionised knot of gas.

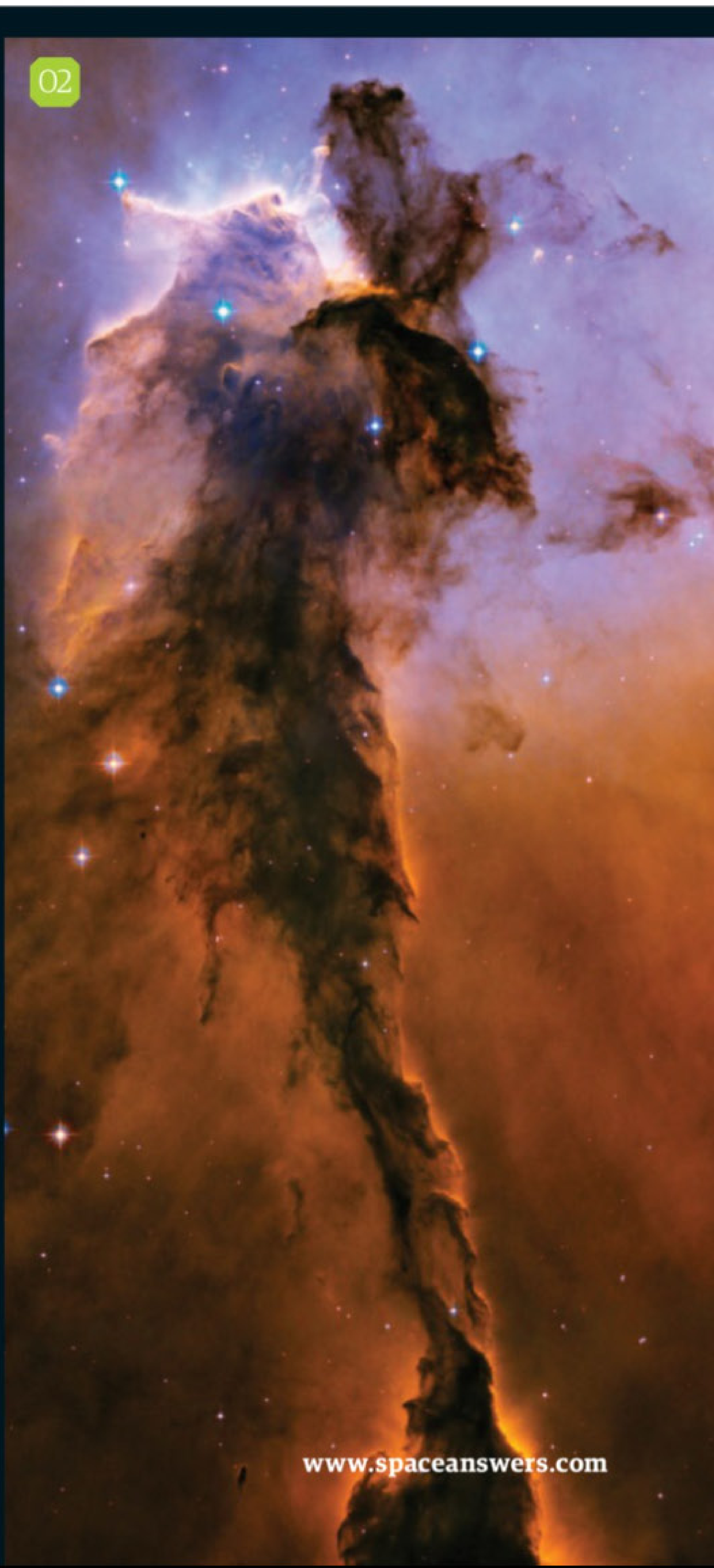
3. NGC 6611
This star cluster is the powerhouse of the nebula. The massive young stars spew ionising radiation into the surrounding molecular dust and have carved a hollow into the gas cloud.

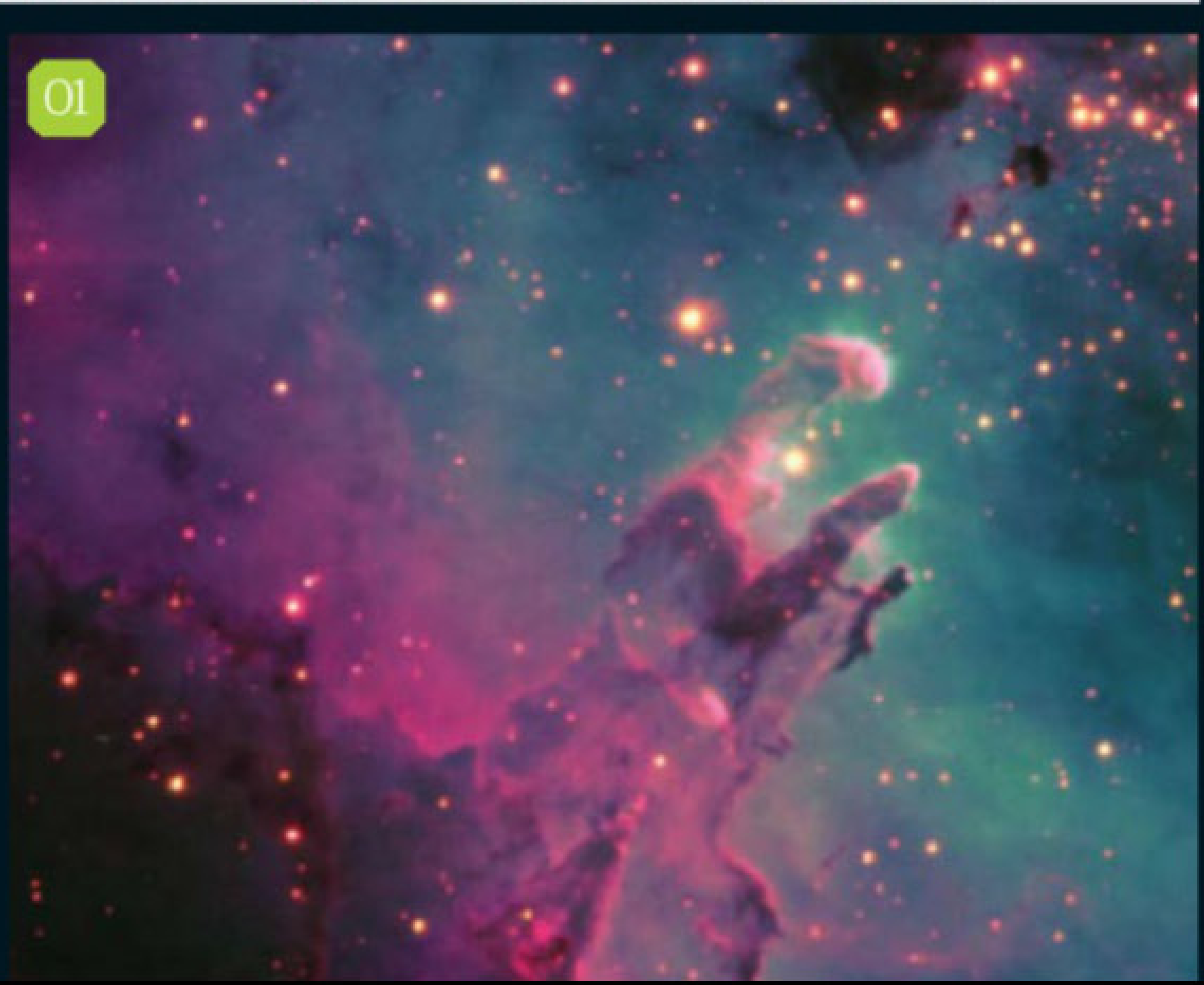
4. Dust lanes
The dark channels of cold dust that twist through the gas clouds of the Eagle nebula are made up of particles of silicon and carbon.

5. Stellar EGGs
Evaporating gaseous globules, or EGGs are dense regions of hydrogen gas thought to give rise to protostars.

6. Bright-rimmed clouds
Just like the tips of the pillars, glowing regions of dust and gas represent areas of new star formations, where shock waves have triggered local collapse.







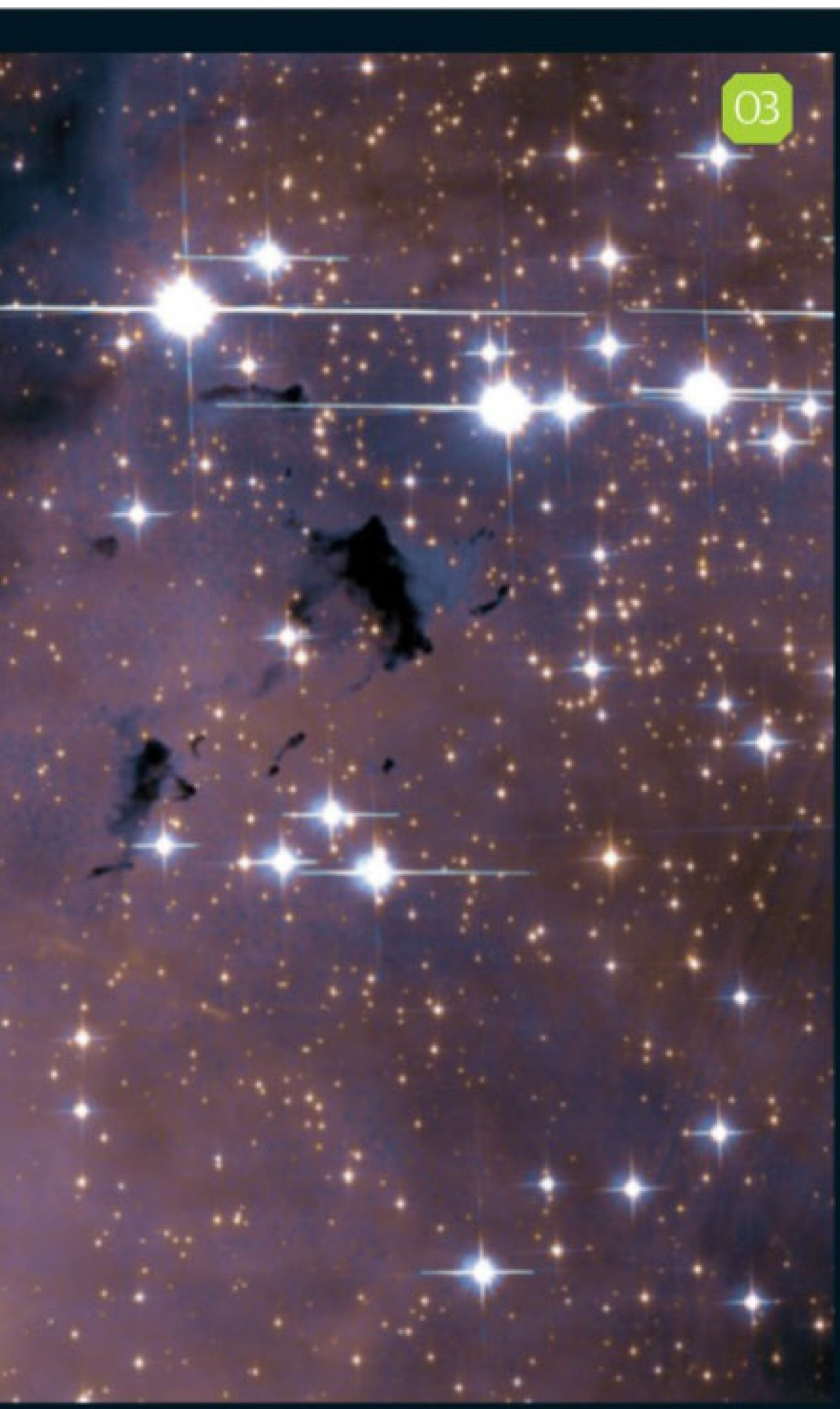
the pillars, the dense EGGs accumulate matter from the molecular cloud, gradually becoming massive enough to initiate nuclear fusion.

Young stars are visible within the pillars, concentrated around the locations of the EGGs, indicating recent star-formation activity, but whether new stars are still being formed in this area is unknown. It's thought that star formation within the pillars has ceased and that as the gas and dust is blown away, the last new members of the cluster will be revealed.

On the other side of the nebula there are still areas displaying signs of active star formation. The stellar spire, often described as a fairy perched on a pedestal, projects inwards from the western edge of the nebula. It's a 9.5-light-year stretch of molecular gas, containing dark lanes of fine carbon and silicone dust, with a band of new, hot stars near the cap. These have generated a shock wave that's battering and compressing the molecular gas of the spire.

A dense region of gas resembling a Herbig-Haro object is visible within the cap of the spire. These objects are generated where the shock waves created by new stars collide with nearby dust and gas, lasting for just a few thousand years before dissipating to provide evidence that star formation might still be going on in the nebula. ●

> "As the radiation reaches the tops of the pillars, the gas is boiled away, leaving visible streamers twisting out from the surface"



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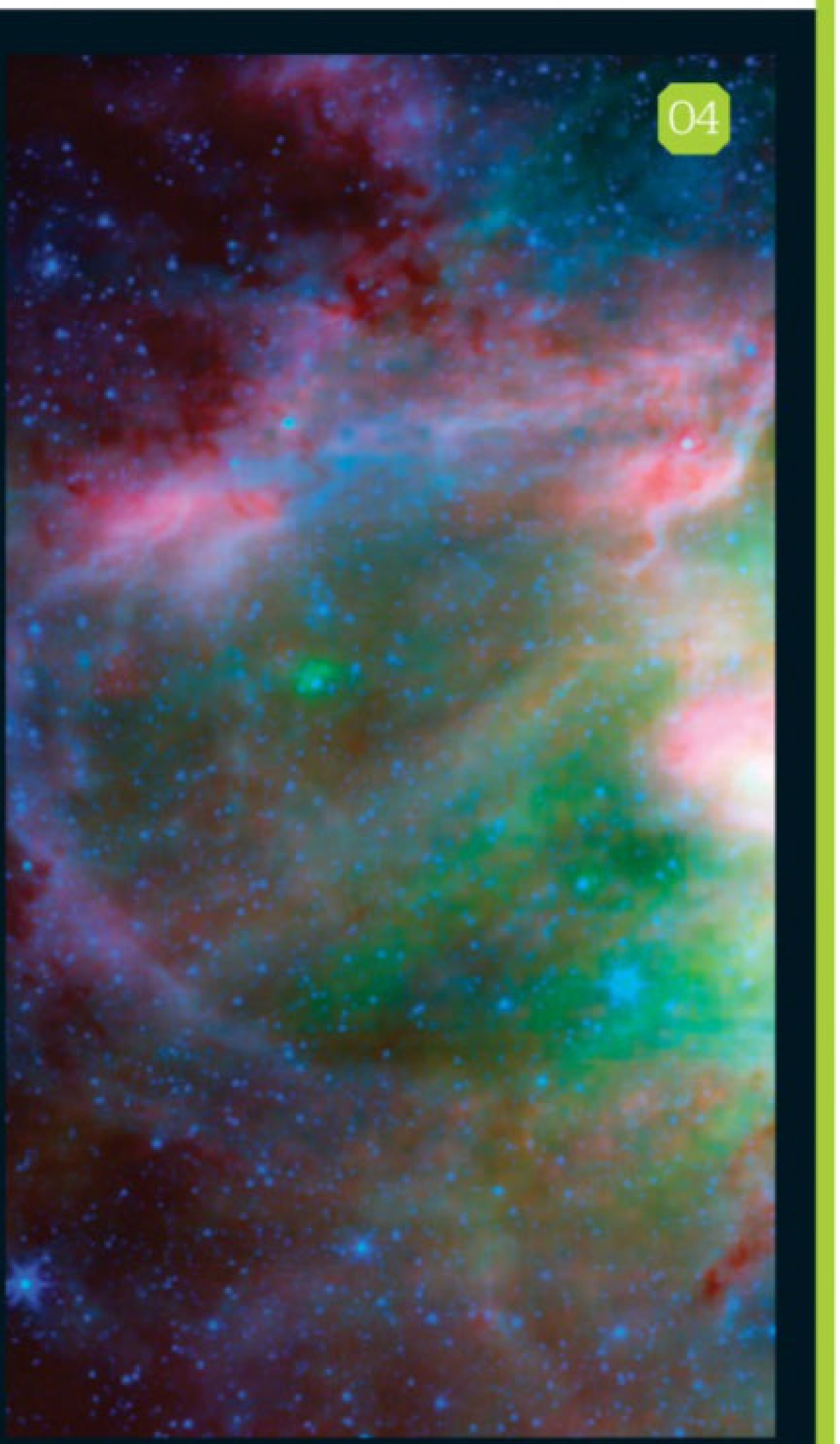

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Eagle nebula by numbers

Fast facts and figures about M16

7,000 ly

The Eagle nebula is 7,000 light years from the Sun.

5.5 million years

The star cluster that formed the Eagle nebula is 5.5 million years old.

32

The iconic image of the Pillars of Creation is actually a composite of 32 separate images, representing the light emissions of sulphur, hydrogen and oxygen.

97.1 trillion km

The column of dust and gas that makes up The Spire is 97.1 trillion kilometres tall.

10K

Most of the gas in the Eagle nebula is barely ten degrees above absolute zero.

70ly

The wingspan of the Eagle nebula measures 70 light years across.

4

There are four massive gas columns in the nebula: the Pillars of Creation and The Spire.

Imaging the nebula

Visible light, infrared radiation and X-rays come together to reveal the beautiful inner workings of the Eagle nebula

In true colour, the Eagle nebula is a haze of glowing red gas, surrounding a bright open cluster of blue and white stars. The red glow is produced by molecular hydrogen gas, excited by ultraviolet radiation released by the stars within the nebula. As the molecules fall back down to their resting energy state, they release photons of red light, causing the nebula to glow.

Not all of the gas cloud is composed of hydrogen; other ions and molecules in the nebula also emit visible light when energised by UV radiation. Unfortunately, most of these emissions are towards the red end of the spectrum and although they are different wavelengths, it's not possible for the eye to distinguish between them. In order to observe the distributions of the various components of the Eagle nebula, as well as to get a better understanding of its dynamics, instruments like the Hubble Space Telescope use filters to selectively image one wavelength of light at a time - essentially enabling astronomers to map the distribution of the gases in the molecular cloud.

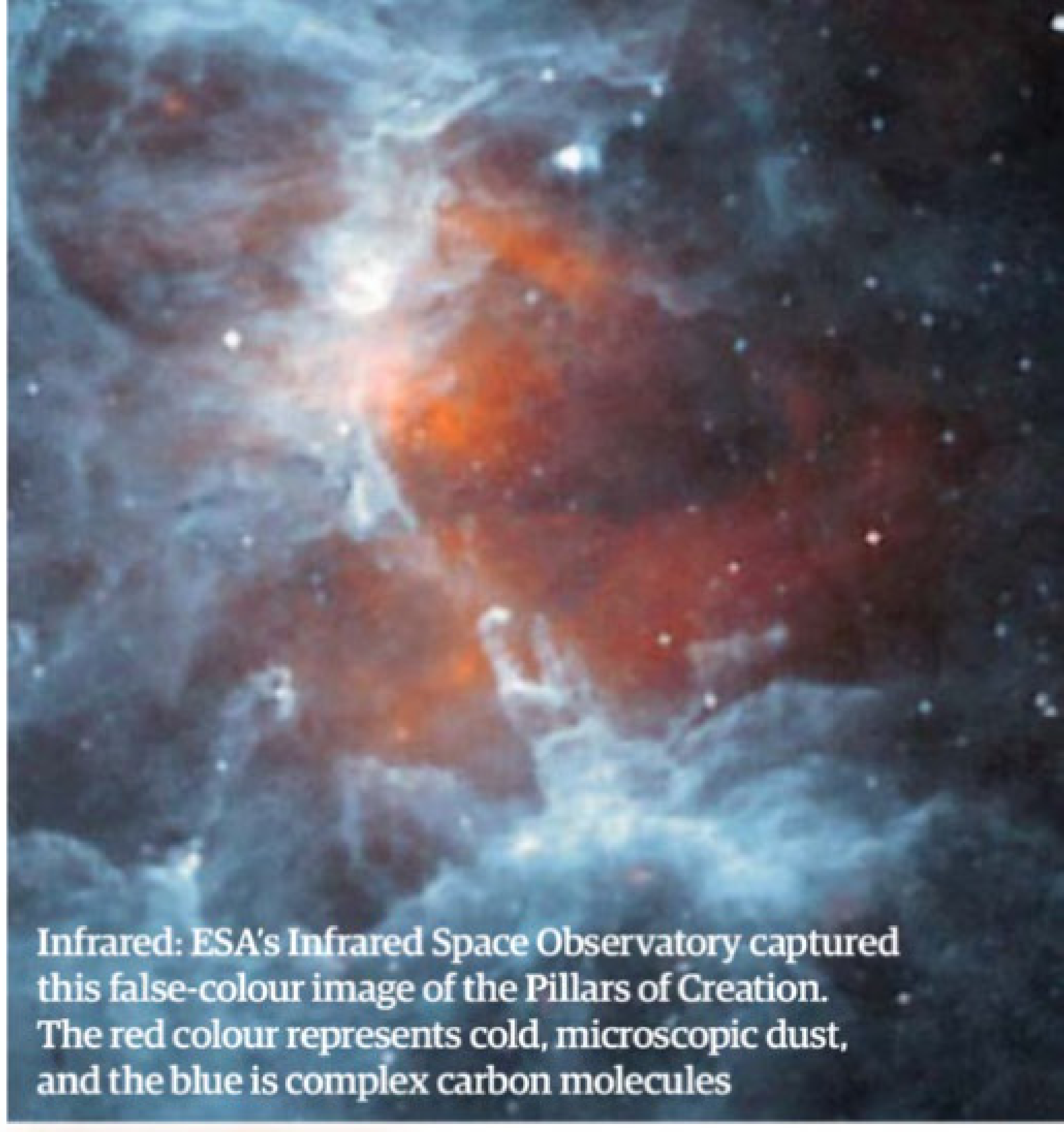
The famous image of the Pillars of Creation, captured by the Hubble Space Telescope in 1995, is actually a composite of images taken through different filters, each focused on a separate wavelength. In combination, these separate images show the dark sulphur-containing dust columns glowing faintly red, with a surrounding green-blue mist of hydrogen and oxygen.

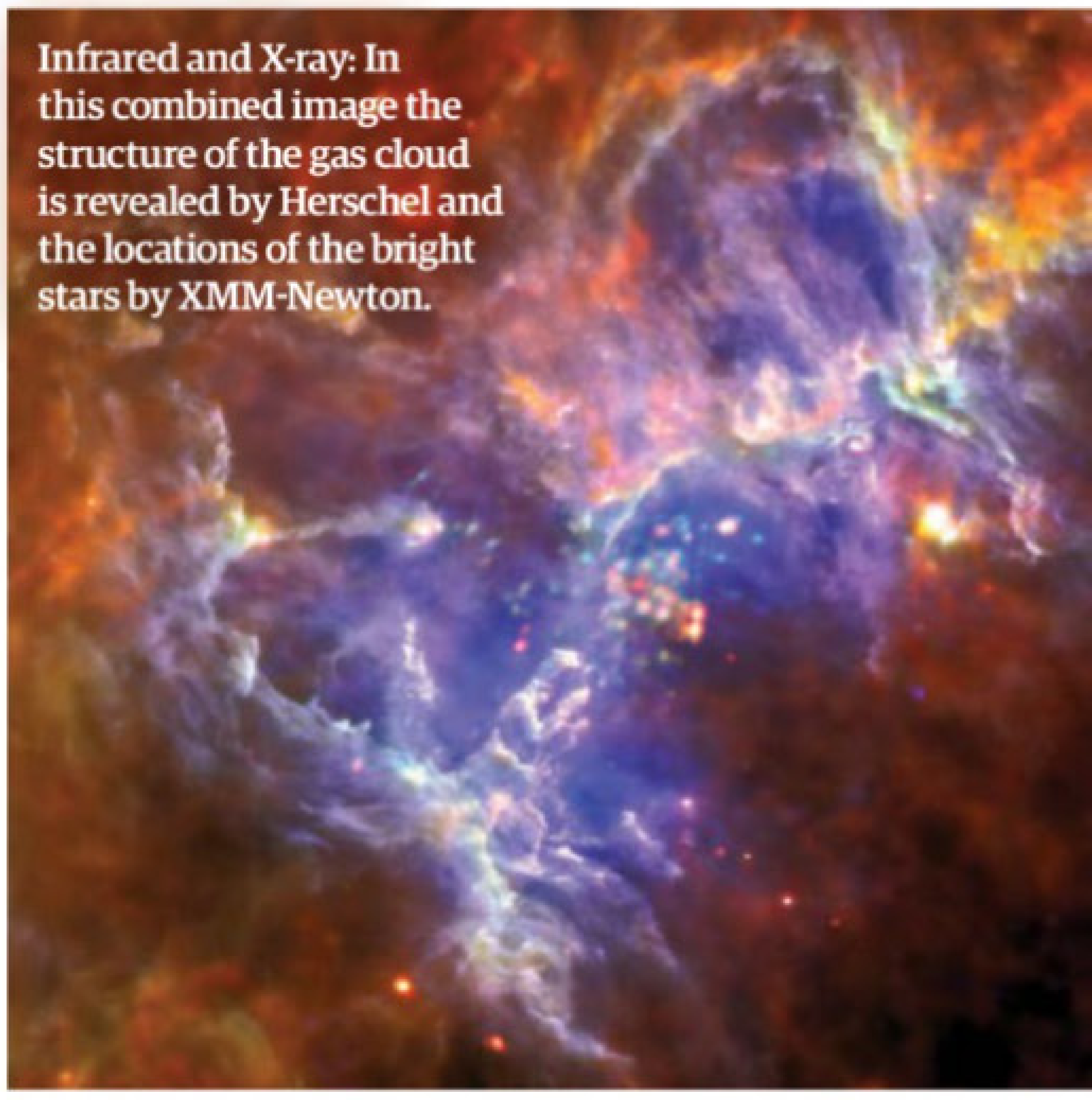
The glowing HII region of the nebula is easy to see, but the dark, cold molecular cloud obscures most of the visible light behind it. However, the longer wavelengths of infrared light are able to penetrate through the dust and can be used to generate a heat-map to pinpoint the locations of hidden stars.

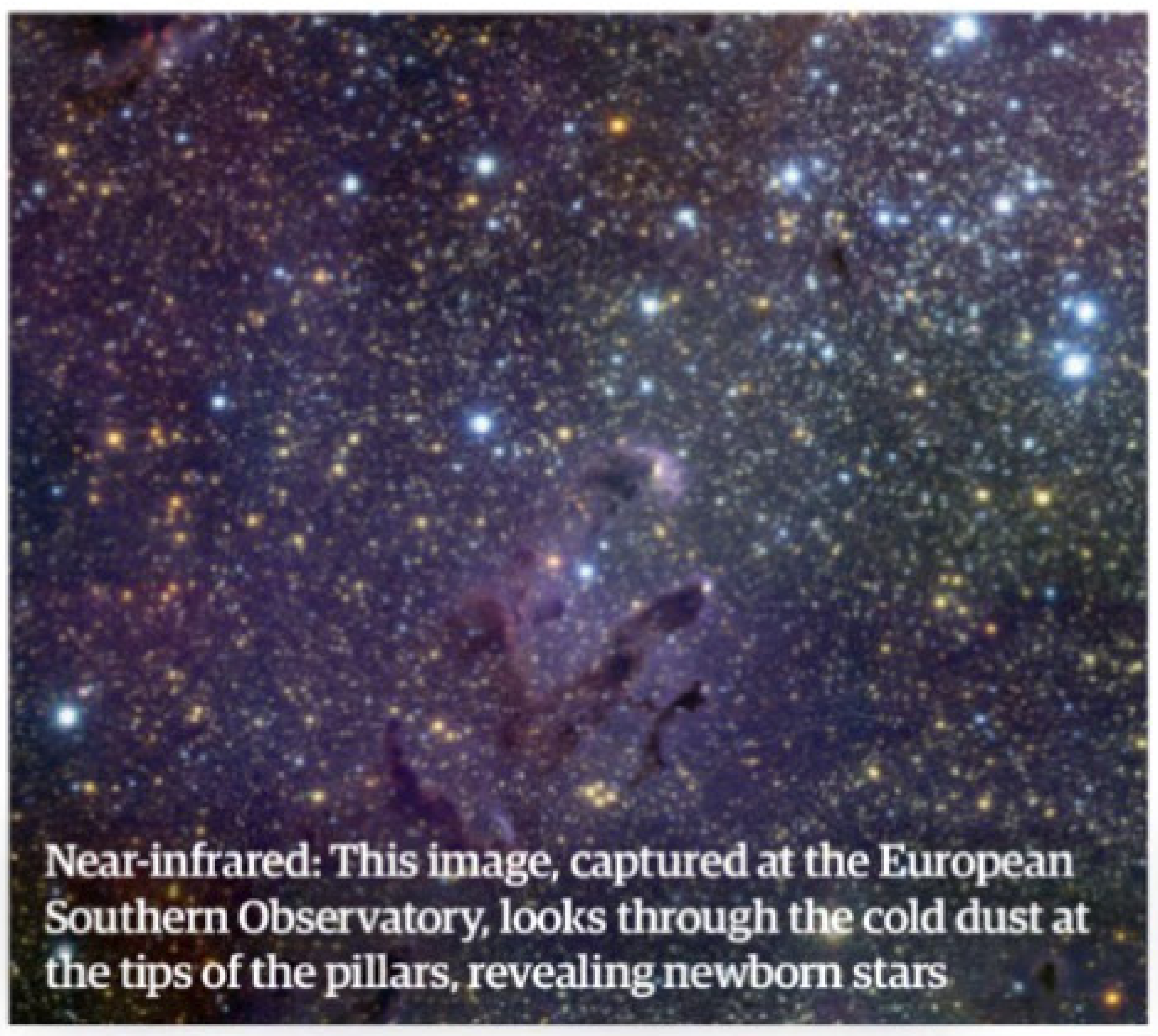
The European Southern Observatory's wide-field telescope, ANTU, has been used to probe the Eagle nebula for near-infrared emissions. These longer wavelengths render the Pillars of Creation almost transparent, enabling astronomers to look at the dense gaseous EGGs inside. These potential new stars are normally entirely obscured by the dust, but infrared images revealed over 70 warm EGGs nestled under the caps of the pillars. Several of these even have hot stars embedded in their tips, though whether the stars gave rise to the EGGs or the EGGs to the stars is not currently known.

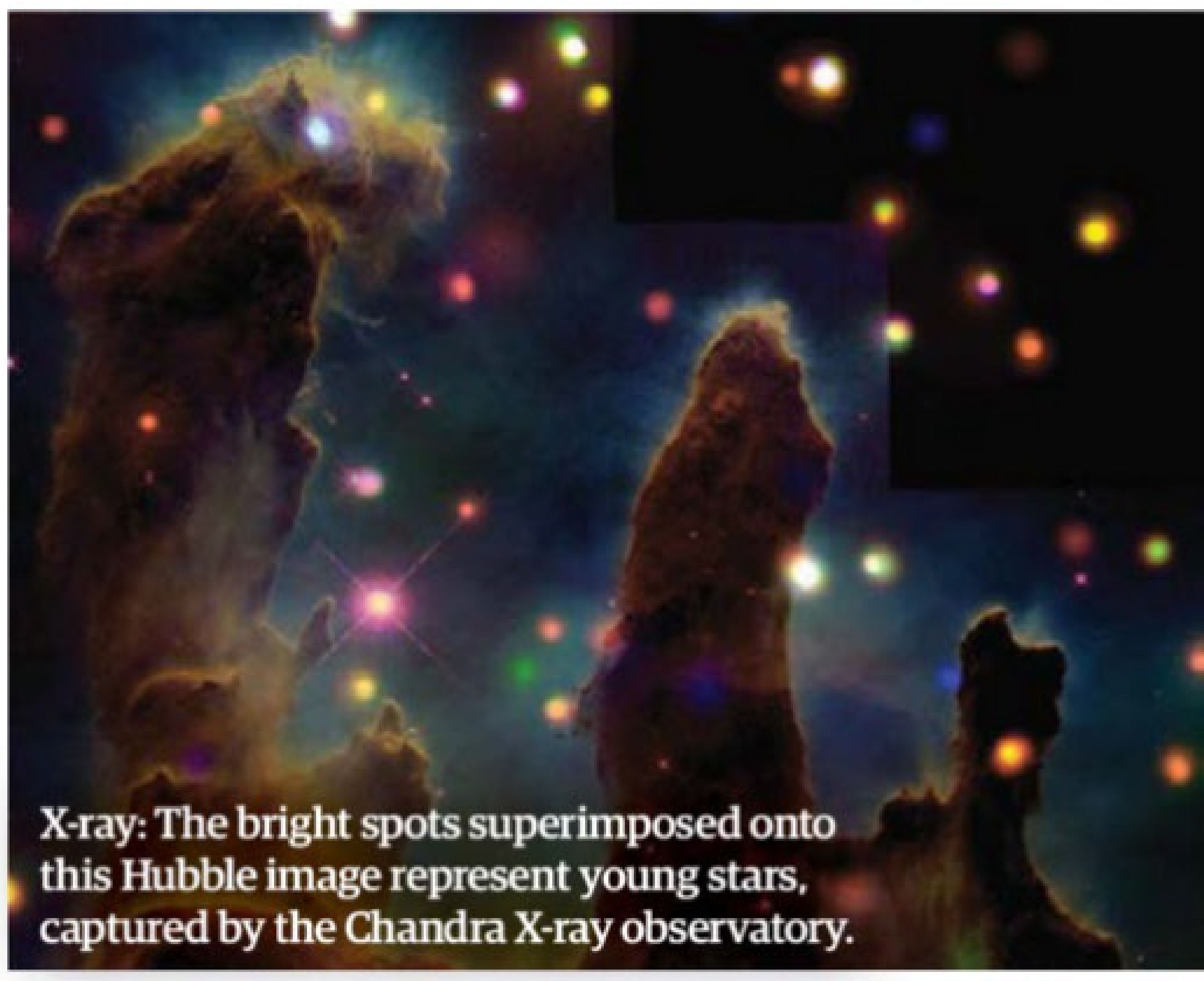
Longer wavelengths of infrared light, as detected by the European Space Agency's Infrared Space Observatory satellite and Herschel Space Observatory, reveal colder areas of the nebula. The majority of the molecular dust cloud is barely above absolute zero, but the faint infrared emissions from the cold clouds reveal the eerie outline of the frigid outer edges of the nebula. These cradle regions of relative warmth (-200 degrees Celsius/-328 degrees Fahrenheit).

The ESA's XMM-Newton and NASA's Chandra X-ray observatory, have both scanned the Eagle nebula for the bright X-ray emissions given off by young stars. The images don't reveal a lot about the structure of the dust cloud but when superimposed onto the visible light images captured by Hubble, or on infrared images of the nebula, it becomes clear that most of the new stars are in the central cavity. Few are forming near the remaining dense dust at the pillars, showing that the nebula is coming to the end of its active life. ●


Infrared: ESA's Infrared Space Observatory captured this false-colour image of the Pillars of Creation. The red colour represents cold, microscopic dust, and the blue is complex carbon molecules

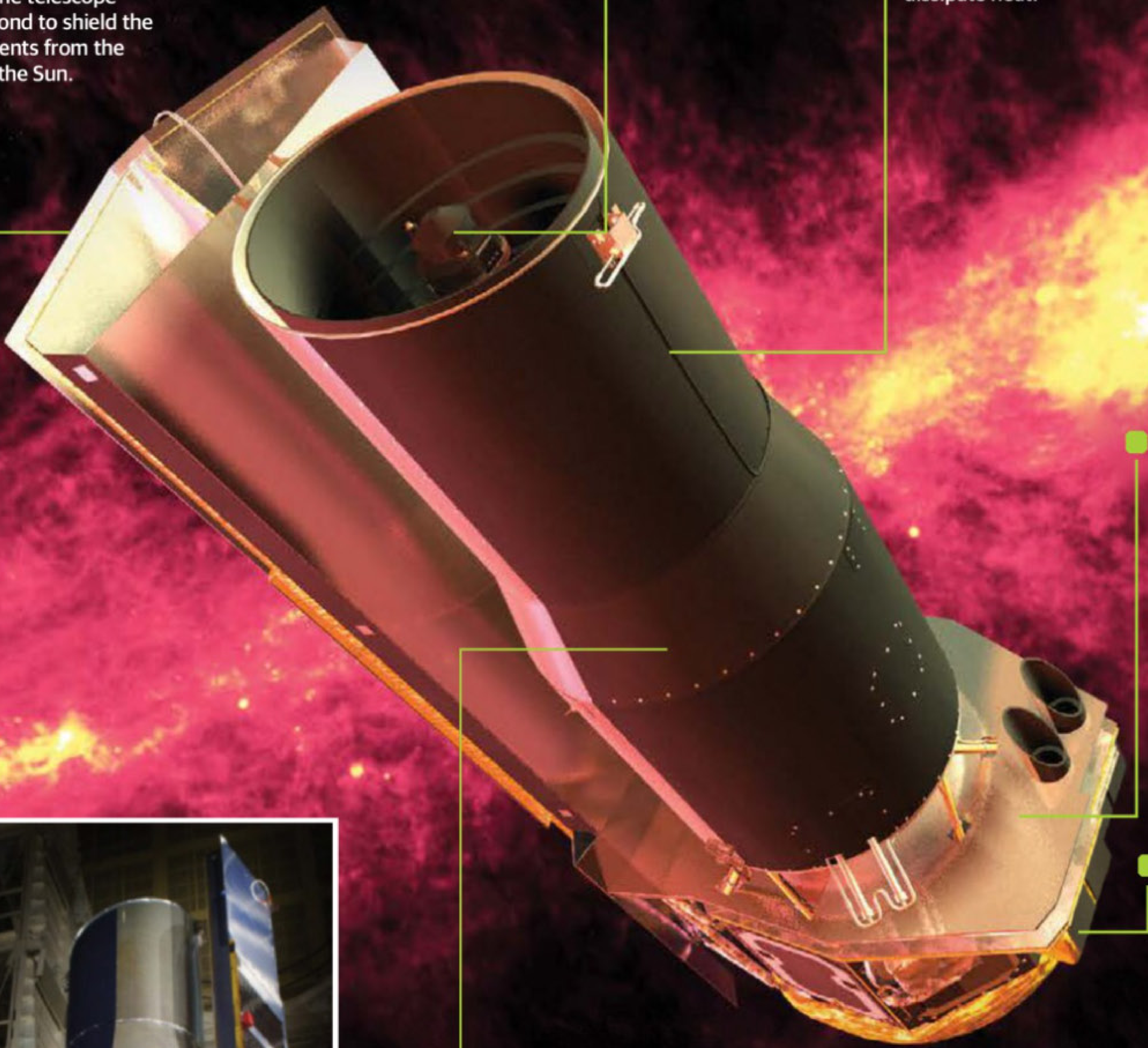

Infrared and X-ray: In this combined image the structure of the gas cloud is revealed by Herschel and the locations of the bright stars by XMM-Newton.


Near-infrared: This image, captured at the European Southern Observatory, looks through the cold dust at the tips of the pillars, revealing newborn stars


X-ray: The bright spots superimposed onto this Hubble image represent young stars, captured by the Chandra X-ray observatory.

True colour: This image of M16, and its neighbour, M17, shows the visible red glow of ionised molecular hydrogen gas

Spitzer Space Telescope



Solar panel
The solar panels serve a dual function: first to power the telescope and second to shield the instruments from the heat of the Sun.

Telescope
Spitzer carries a beryllium telescope, 85 centimetres (33 inches) in diameter, with three separate cryogenically cooled instruments – an infrared array camera, infrared spectrograph and a multi-band photometer for imaging in the far infrared.

Outer shell
The outer shell is shielded from the Sun by the solar panels and radiates heat to space, keeping the instruments cool. It's also cooled by vapour from the helium tank, helping to dissipate heat.

Shields
The sensitive equipment is shielded from heat generated by the solar panels, or in the spacecraft bus, using a series of shields cooled by helium.

Star-tracker
An autonomous star-tracker, attached on the opposite side to the solar panel, uses pattern recognition to point the telescope in the direction of the correct star system.

Multiple instrument chamber
Infrared light is essentially heat radiation. The scientific instruments are cryogenically cooled so that minute changes in temperature can be recorded easier.

Technicians make final changes to the Spitzer Space Telescope before its launch in 2003

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Mission profile

Spitzer Space Telescope

Launch: 25 August 2003
Primary mission ends: 15 May 2009
Length: 4.45m (14.6ft)
Mass: 950kg (2,094lbs)
Orbit type: Earth trailing, Heliocentric
Major discoveries:
Before its coolant ran out in 2009, NASA's Spitzer Space Telescope discovered Saturn's largest ring, became the first telescope to detect the light emitted by a small planet outside of the Solar System and made a complete map of the closest star-forming clouds.

Astronomer Royal

All About Space speaks to much-celebrated Astronomer Royal Martin Rees about his contribution to the Big Bang theory and life on other planets

Interviewed by Ben Biggs

INTERVIEW BIO

Martin Rees

Renowned Astronomer Royal Martin Rees is best known for his work on some of the most exotic and extreme objects in the cosmos: black holes, quasars, gamma ray bursts and the early universe. He's written several books, has received numerous prestigious academic awards, he was the president of the Royal Astronomical Society and even has a seat in the UK's House of Lords, as Baron Rees of Ludlow.

Tell me about your role as Astronomer Royal - what does it mean for you?

Astronomer Royal is just an honorary title given to someone that's active in astronomy now. It used to be the person who ran the Greenwich Observatory and the title dates back to 1675, but the observatory has since become a museum... The title of the Astronomer Royal is now given to a senior academic astronomer, no longer to the person that runs the Greenwich Observatory.

You've had this post for nearly 20 years, could you pick out a few highlights?

Obviously there have been some huge highlights in astronomy during that time. We've learnt a great deal about how the universe is expanding and that this expansion is speeding up and not slowing down. I think the most exciting development for most of us has been the realisation that most of the planets orbiting the sky have retinues of planets orbiting them. The night sky is really interesting because we know that every star is actually a planetary system.

What do you hope to see from the big telescopes of the future?

Of course, they're a big step forwards from what we have now, where the best telescope in the world is the European VLT, an eight-metre [26-foot] telescope in Chile. It will be a big change when we have these larger ones. There are two being planned in America plus the unimaginatively named European Extremely Large Telescope, which plans to have a 39-metre [128-foot] mirror. That will have the capability to see very faint objects and I'll be interested in looking as far back in time as we can and therefore as far away as we can. Also, I'll be very interested in what it can do for planets around other stars because, in order to take images of planets around another star you've got the problem of looking at a firefly very near to a searchlight, as it were, only much fainter.

The E-ELT will have the combination of collecting power and angular resolution to [see them]. It will enable astronomers using a high-level spectrograph to distinguish between the light of the star and the much smaller contribution coming from the reflected light of the planet. [We will] thereby learn something about the planet, whether it's got lots of clouds, topographical features, the length of the day, etcetera.

What's your position on whether or not life will be found on these planets, or indeed within the Solar System?

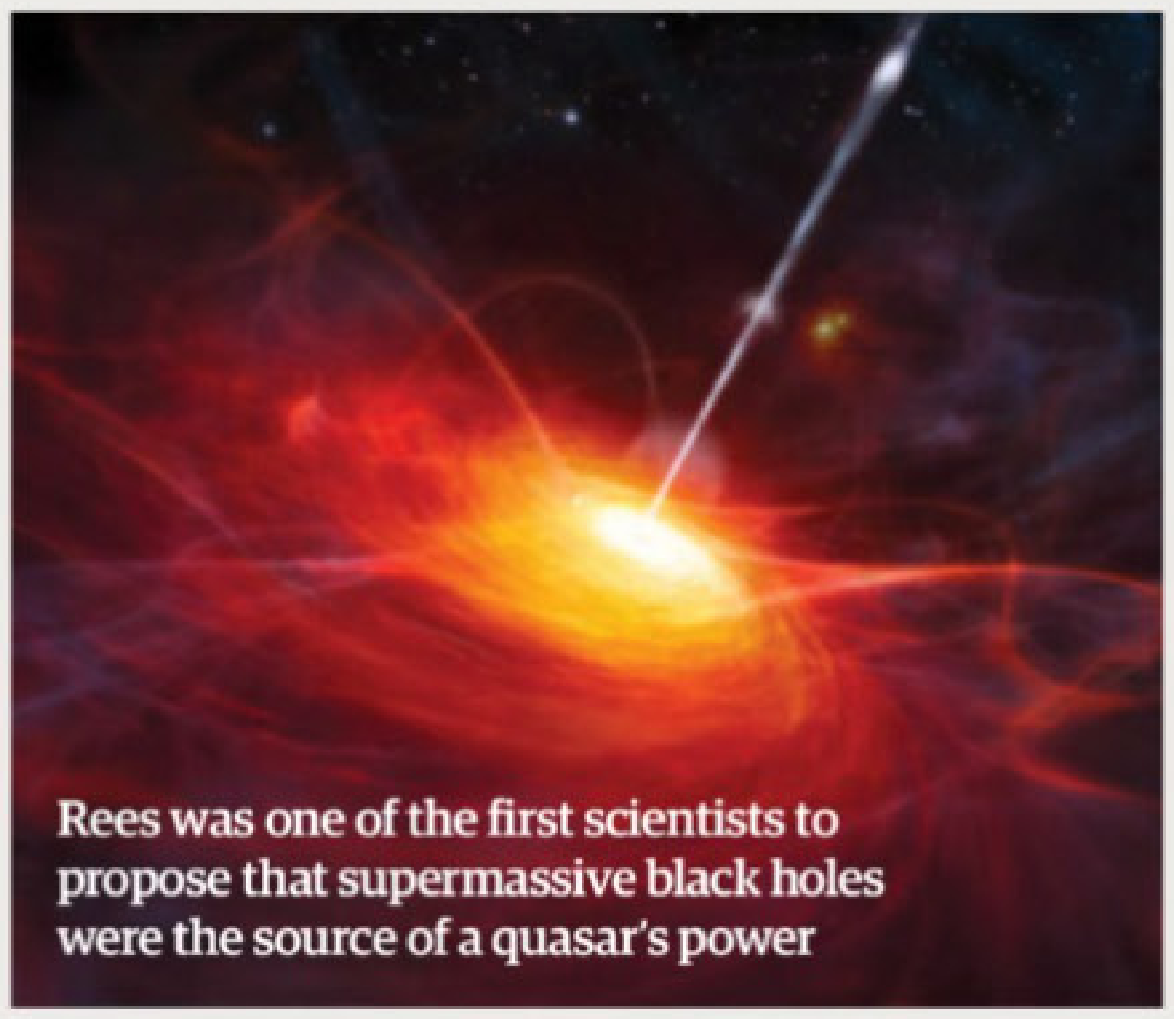
Well... I think we just don't know. We don't really understand how life began on Earth. We understand how it evolved with Darwinian selection but we don't understand how the transition from complex chemistry to the first metabolising and reproducing systems occurred. We therefore don't know whether it was a very rare fluke or whether it was something that would have happened anywhere given the right sort of environment.

I think most of us would be very surprised if there were any past life anywhere in our Solar System: people are looking for evidence of past life on Mars as you know and there could be life under the ice of Enceladus or Europa. But that's very optimistic. It's very important to look for it because even if we were to find the simplest form of life and we could be sure it occurred independently, that would straight away tell us that life must be very common in the galaxy.

Now we know that there are a billion planets rather like the Earth orbiting other stars in our galaxy, that makes everyone suspect that there's very likely to be life. We've no idea how likely it is, we've no idea how simple life would evolve into anything as complex as our biosphere, or evolving intelligent creatures, but it's a very exciting prospect. In a decade or two, we're going to have clues to the answer.

Do you think it possible that life was seeded on Earth from other planets?

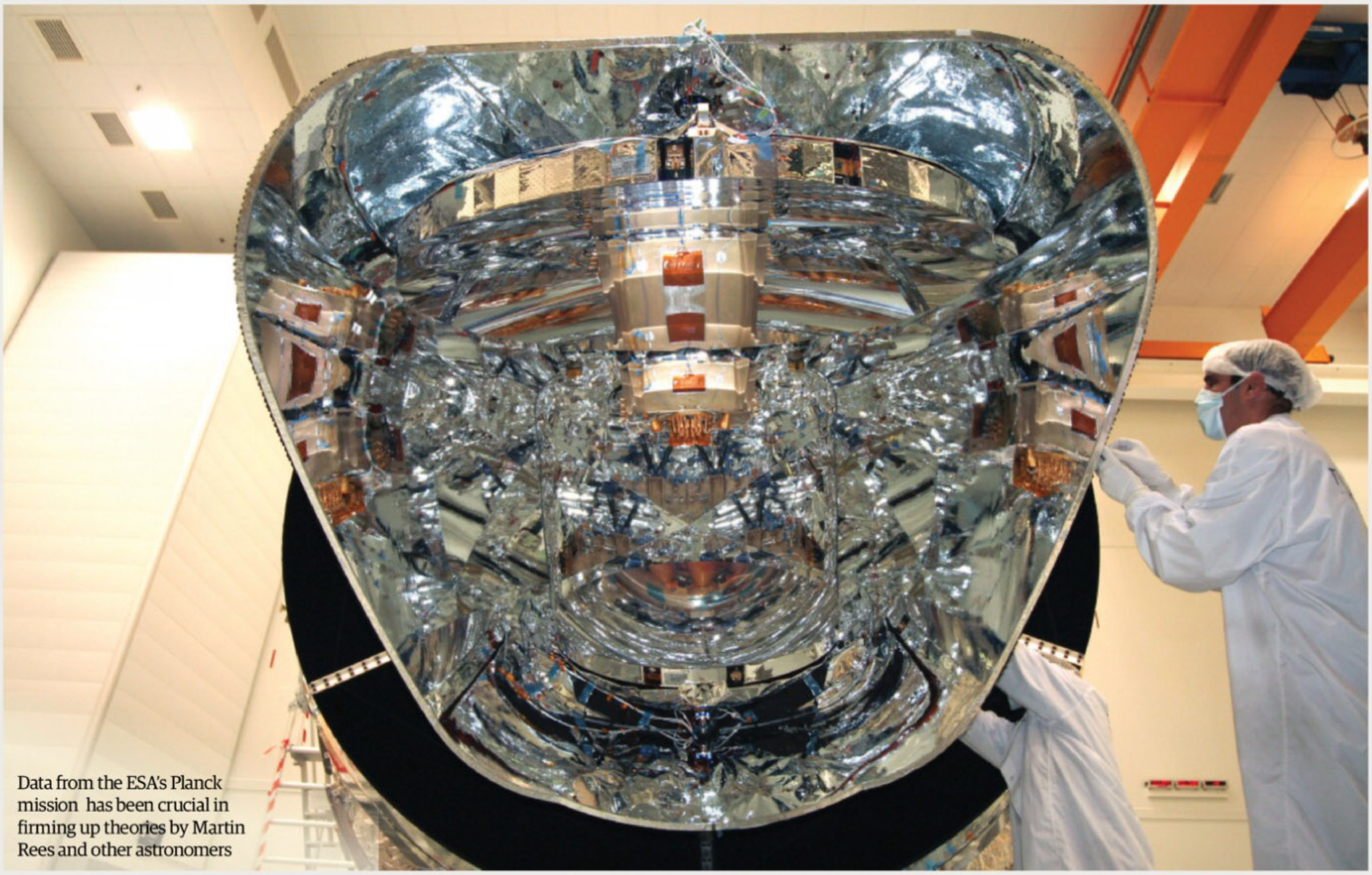
I think it's wrong to have any strong beliefs on these topics where it's very uncertain, but it seems to be slightly unlikely. It seems to be more likely that life on Earth started here, although it's indeed possible that life on Earth came from Mars. Even if we did



Rees was one of the first scientists to propose that supermassive black holes were the source of a quasar's power

"Even if we were to find the simplest form of life, that would straight away tell us that life must be very common in the galaxy"

Rees delivers his acceptance speech at the 2011 Templeton Prize award ceremony



Data from the ESA's Planck mission has been crucial in firming up theories by Martin Rees and other astronomers

find life on Mars, we wouldn't be sure whether it had the independent origin.

You've made notable contributions to our understanding of the CMB and quasars, how has the universe changed for humankind since then?
Well I think it's important to realise that the progress made in the last few decades is 95 per cent due to the advances of instrumentation and only slightly due to theorists like myself. It's the experiments that have been marvellous in making advances in the subject. I think, as regards quasars and galaxies, we've come to understand that, at the centre of a galaxy there is almost always a large black hole and the size of the black hole is correlated with the size of the galaxy. That leads us to suspect that the formation and growth of the galaxy was somehow linked to the formation and growth of the black hole. This is one thing that many of us are trying to puzzle out.

We've made a great deal of progress in understanding quasars and they're not just important in their own right but serve as probes for the intervening material. Quasars have enabled us to understand the history of the universe by allowing us to infer how much gas there was and how hot the gas was from the first billion years of the universe up to the present. [We now also] understand how the first stars and galaxy formed and lit up the universe and what the subsequent history was...

Now the other big advance of course has been understanding what happened long before galaxies formed, understanding the early phase of the Big Bang. It's been nearly 50 years since the so-called afterglow of creation, evidence for microwave radiation pervading all of space. Penzias and Wilson discovered that accidentally in 1964 and we now have very detailed observations of this radiation. In particular, we know it's not completely uniform over the sky. We've learned from a number of experiments, just recently from the ESA Planck satellite, about how the temperature varies a bit from place to place. This tells us that the early universe was slightly lumpy. It's rather like on an ocean where you have waves of different heights.

Numerical calculations have shown that if the early universe were indeed lumpy in the way it's observed to be from the Planck data, gravity acted on those fluctuations and then after 13 or 14 billion years, the universe would actually look like ours does. So we have a very good theory that the structures we see in our universe, the galaxies and clusters, have emerged by gravity acting on initial, slight density irregularities present when the universe was young. That's a great achievement – it links the present universe to the very early universe.

Another big step forward has been to go back even further to understand why the universe, as observed by the Planck spacecraft, contains these fluctuations. What is amazing here is that this takes us back to what happens in the first trillionth of a trillionth of a trillionth of a second, when everything we see out to the most distant galaxies was squeezed down to the size of a tennis ball. The fact that we can talk with a straight face about this extraordinary achievement is simply amazing.

50 years ago, it wasn't clear whether there was a Big Bang at all and now we know what the universe was like back to when it was a nanosecond old... it's an amazing progress in understanding our origins.

> "Everything we see out to the most distant galaxies was squeezed down to the size of a tennis ball"

You must have been quite interested in the results of the BICEP2 experiment?
We have to wait for confirmation because there will be some other experiments later this year, including a new set of data from the Planck spacecraft that will firm this up. But if it's correct... it gives us the confidence that we can actually infer something quantitative about the very beginning of the universe and also the physical processes when the universe

HRH the Duke of Edinburgh bestows the Templeton Prize on Martin Rees

was so compressed that quantum effects were important. We're used to the idea that quantum theory is important in the microscopic world of atoms, not in the world of astronomy. But when the universe is squeezed down to the size of an atom, we have to think of quantum effects on the scale of the entire universe.

You've also written a book on the future of humanity. Do you think that humanity needs to move off this planet order to survive even into near future?

I hope that there will be pioneers living away from the Earth a century from now but I think we mustn't kid ourselves that there's an easy way to escape from the Earth. There's nowhere in our Solar System that's going to be a comfortable place to live. We can certainly say that it won't even be as comfortable as living at the South Pole, for instance. So the idea that there will be mass emigration into space is really complete nonsense.

The problems of the Earth have to be solved here on the Earth and we can't escape from them. I think we can guarantee a bright future here on the Earth but it will be a bumpy ride through this century as technology becomes more powerful and humans selectively produce more challenges to the environment and climate of the planet. It's here that there are risks that I have written and worry about. The more powerful technology gets, [it not only] has an up side but a down side.

The Arecibo Observatory in Puerto Rico. Rees supports the work of SETI, but thinks it unlikely that life will be found elsewhere in the Solar System

The team behind the Planck spacecraft's Cosmic Microwave Background-exploring mission. The Big Bang theory has come far in the last 50 years

You could compare it to some children playing with big, dangerous toys?

That's right and I think we ought to make sure we don't unthinkingly cause global environmental damage. We've got to ensure we don't have village idiots in a global village who can cause catastrophe by error, or by terror.

You've received numerous awards for your work, what's your proudest moment as an astronomer?

I wouldn't like to single out anything. I've been very fortunate to work in astronomy in this country as part of a very vibrant community... it's been wonderful. I'd like to add that I would have derived less satisfaction from being an astronomer if I could only talk to a few fellow specialists about it. It's a big bonus for us in astronomy that we can share our wonder of new discoveries with the wider public. I enjoy very much the interactions with the wider public of amateur astronomers and the more general public because they are fascinated by these discoveries. After all, the cosmos is part of our environment and the sky is the one feature that's been shared by all humans throughout history. ■

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Opening Pandora's cluster

A glimpse into the burning chaos unfolding inside this giant structure

This splatter of colour interrupted by scatterings of galaxies is Pandora's cluster, a cosmic crash that took place over a period of roughly 350 million years.

Just like its namesake, Pandora's Box, the cluster is made up of a variety of phenomena. This strange celestial object includes two bow shock features, as well as a gaseous cosmic slingshot that was kick-started by a collision of at least four galaxy clusters.

The image is made up of a combination of data grabbed by space-bound missions (the Hubble Space Telescope and Chandra X-ray Observatory) along with the Earth-bound instruments the Very Large Telescope and the Japanese Subaru telescope.

The galaxies in this gigantic cluster make up less than five per cent of its mass, while around 20 per cent is made of gas that's so unbearably hot it glows in a blazing red, representative of X-rays. Blue colouring marks around 75 per cent of the cluster, showing the distribution of elusive and invisible dark matter. This exotic material rarely interacts with normal matter, or even itself, except through its gravitational pull.

Pandora's cluster, also referred to as Abell 2744, is a gigantic galaxy cluster made from the cosmic crash of at least four smaller gatherings of galaxies

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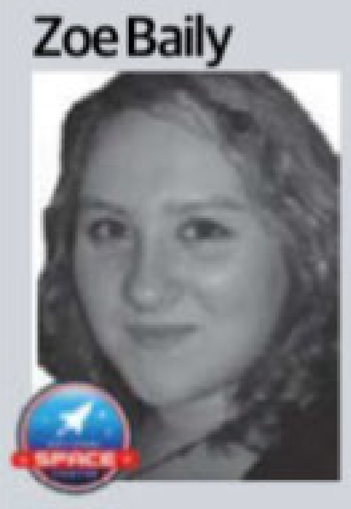
Sophie Allan

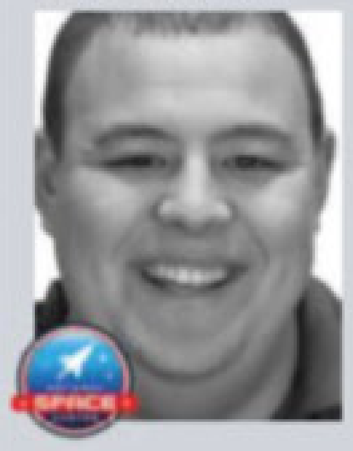
National Space Academy Education Officer
■ Sophie studied Astrophysics at university. She has a special interest in astrobiology and planetary science.

Zoe Baily



National Space Centre
■ Zoe holds a Master's degree in Interdisciplinary Science and loves the topic of space as it unites different disciplines.

Josh Barker

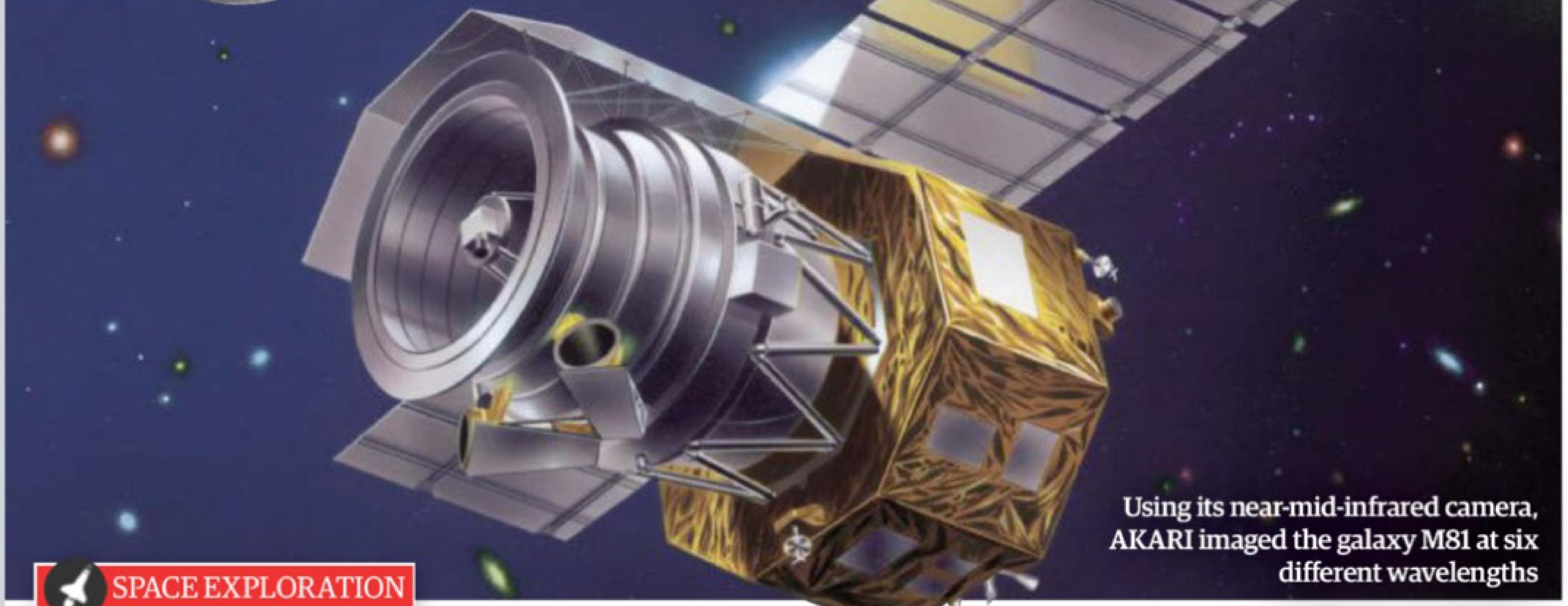


Education Team Presenter
■ Having earned a Master's in Physics and Astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

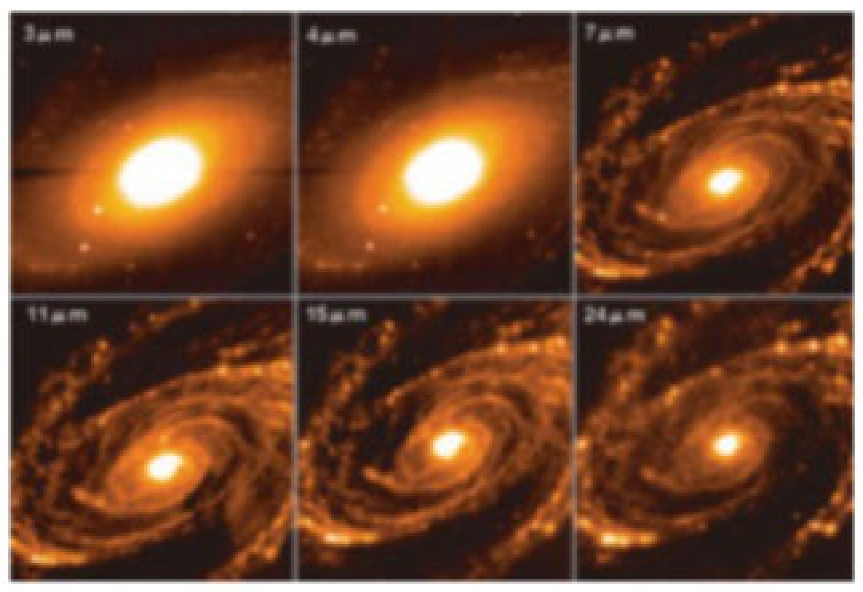
Gemma Lavender

Staff writer
■ Gemma has been elected as a fellow of the Royal Astronomical Society and recently joined the **All About Space** team on a permanent basis.

Astronaut Alan Bean takes a sample of lunar soil



Using its near-mid-infrared camera, AKARI imaged the galaxy M81 at six different wavelengths



SPACE EXPLORATION

Is AKARI still operating?

Jodie Parry

AKARI is an infrared astronomy satellite developed by JAXA (Japan Aerospace Exploration Agency), with participation of several institutes in Europe and Korea. Sadly it suffered a major electrical failure that rendered its science instruments inoperable and the mission was terminated in November 2011.

Before its termination, the mission successfully studied star formations over three generations in a nebula within the constellation Vulpecula. It also viewed active star formation in the Pinwheel galaxy (M101), as well as dust processing in supernova remnants in the Large Magellanic Cloud. The mission also studied other regions of star formation and evolution in areas of our galaxy before its five-year-nine-month mission came to an end. **GL**

Make contact: @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

SOLAR SYSTEM

Does the Moon have the same nutrients as Earth?

Rosie Brown

Although the Moon and the Earth are thought to have a similar origin, their evolutionary history means that there are significant differences between our terrestrial soil and its lunar counterpart. Here on Earth our atmosphere and climate systems create a water- and oxygen-rich environment for soil to form. In contrast, our Moon has to rely almost entirely on impacts from space debris to physically break up lunar rock to create its fine, powdery lunar soil. This makes the two soils chemically different.

Nutrients are generally defined as compounds that are essential for life and many are created by biological processes. On Earth, nutrients are constantly being recycled and organic material is always being put back into the soil – something that doesn't happen on the Moon. **ZB**

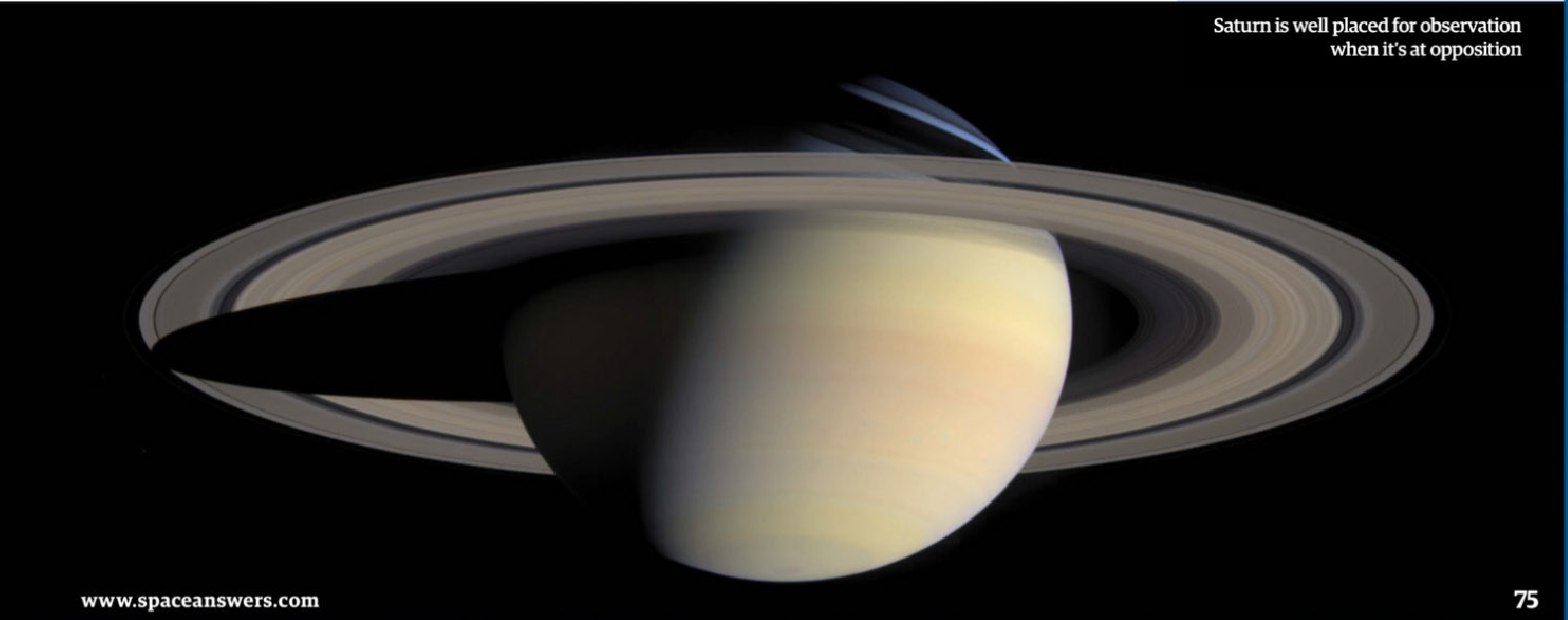
ASTRONOMY

When is the best time to see Saturn?

Yasmin Ford

The best time to observe Saturn is when it's at opposition – this when Earth passes between the Sun and the planet. Not only that, but the ringed planet will be at its closest to Earth at this time where it will appear, at least to us, as a bright-yellow star. However, since this planet is the furthest world we can see with the naked eye, don't expect Saturn to look as bright as Mars and Jupiter are at opposition.

A planet's opposition can last for many weeks, providing the perfect opportunity for observation through binoculars and telescopes as it slowly recedes from Earth. With its system of rings, Saturn is a stunning sight. While it's still visible in the night sky at the moment, it's not at its best – the next opposition is 23 May 2015. **GL**



Saturn is well placed for observation when it's at opposition

DEEP SPACE

American astronomer Jill Tarter holds the Bernard M Oliver Chair for

Is SETI any closer to finding life elsewhere?

Leonard Richards

SETI's search for extraterrestrial intelligence is about to get a boost, but the chances of finding anything are still slim. This year should see the completion of the Allen Telescope Array – a collaboration between SETI and the Radio Astronomy Laboratory at UC Berkeley to develop a specialised telescope array for SETI studies. It will be made up of 350 radio dishes and will vastly improve the sensitivity of the search.

This increased sensitivity won't only improve the ability to search for signs of intelligence, but also enable the discovery of other radio sources and add a strong use to the array. Currently the 'Wow!' signal of 1977 is the strongest candidate for a non-natural radio signal, but it has never been repeated or seen again. **JB**

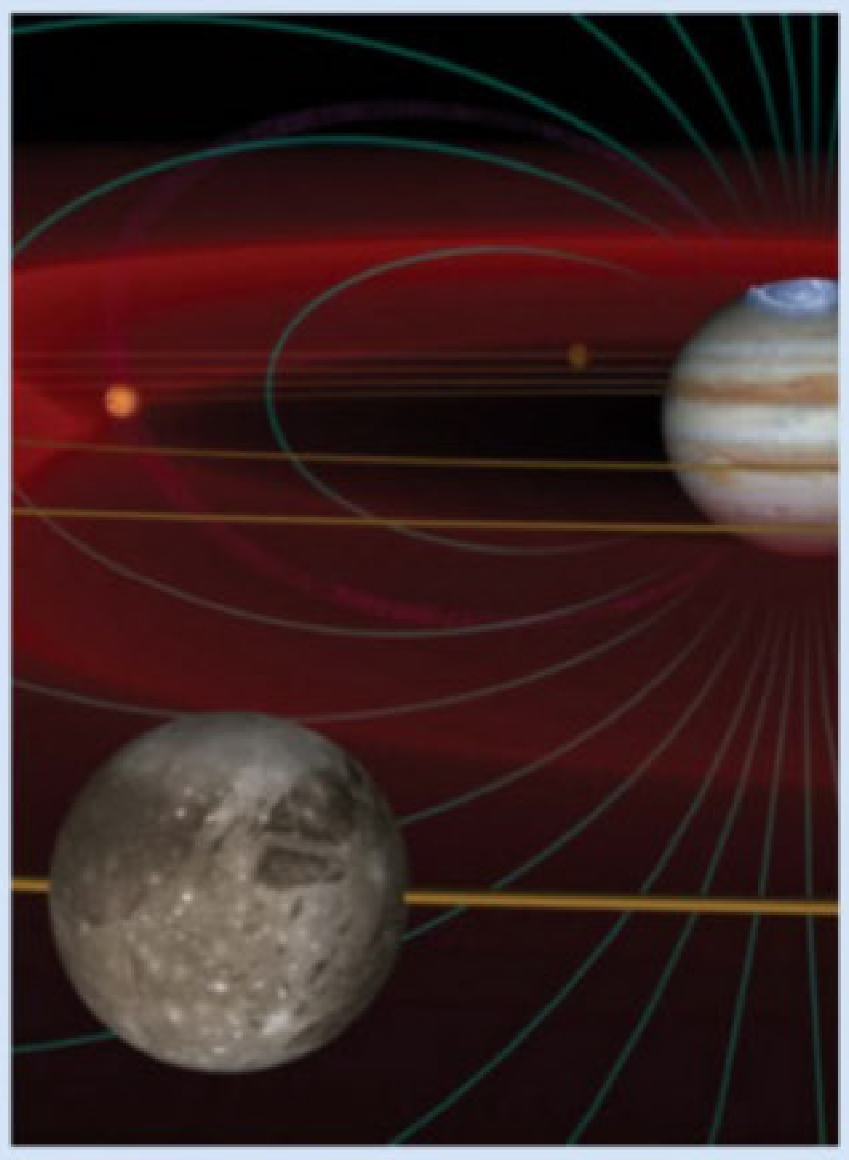
SOLAR SYSTEM

Why haven't Mercury and Mars managed to keep their atmospheres?

Keith James

The short answer is that Mercury is too hot and Mars has no magnetic field to shield it from high-energy-charged particles. Both Mars and Mercury are relatively small planets and so have a low surface gravity. This means that particles are more easily able to escape the atmosphere if given energy. However, size is not everything. In Mars' case the overriding factor in the loss of the atmosphere was a lack of planetary magnetic field. These fields (such as those on the Earth generated by a moving molten-iron outer core) deflect high-energy-charged particles from the Sun known as the solar wind. Mars cooled quicker than the Earth and so lost its magnetic field, enabling the solar wind to strip away the atmosphere over time.

Mercury does have a magnetic field, however the relatively low surface gravity and extremely high temperatures make it almost impossible for it to hold on to any substantial atmosphere. **SA**



Alongside Earth, Venus is the only other inner planet that has managed to hold a substantial atmosphere

DEEP SPACE

Why does NGC 4622 spin backwards?

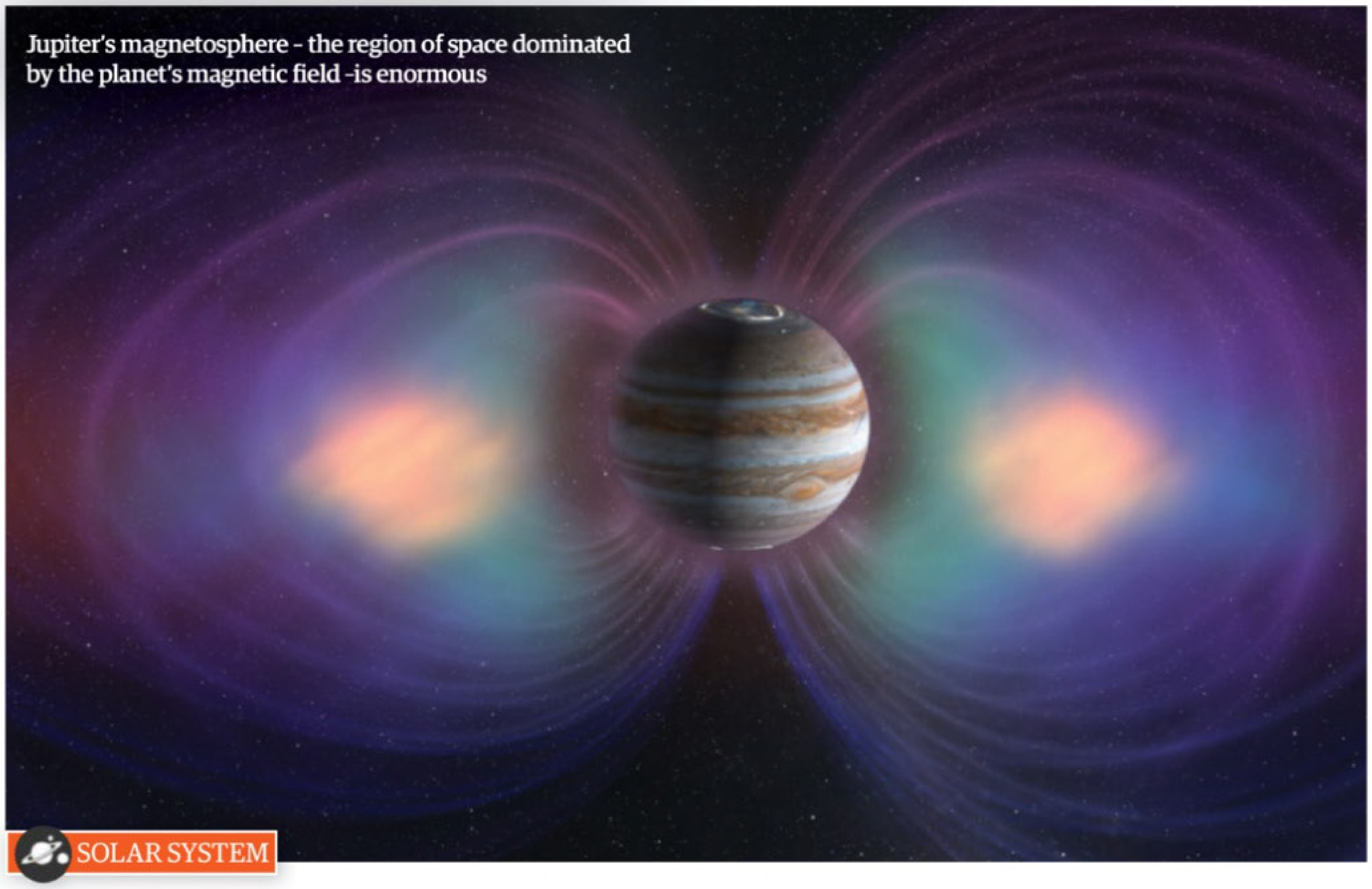
Megan Davies

Spiral galaxies usually rotate in such a way that their arms trail with the tips of the arms winding away from the centre of the galaxy, in the same direction as the galaxy's disk. However, NGC 4622, also referred to as the backward galaxy, strangely leads with the tips of its spiral arms in the opposite direction.

Some experts suggest this phenomenon may be the result of a gravitational interaction between itself and another galaxy. However, others have put forward the idea that the backwards galaxy may be the result of a merger with a smaller object.

The idea of a galaxy that leads with its spiral arms originally met widespread scepticism because it contradicted conventional thought. However, further observations of the galaxy have confirmed its motion. **GL**

Backward galaxy NGC 4622 rests some 111 million light years away in the constellation Centaurus



Jupiter's magnetosphere - the region of space dominated by the planet's magnetic field -is enormous

SOLAR SYSTEM

Why does Jupiter have such a strong magnetic field?

Jack Neville

Larger, complex and up to ten times the strength of Earth's, Jupiter's magnetic field is thought to arise from electrical currents emanating from a rapidly spinning, metallic hydrogen interior.

The planet's field is almost a doughnut shape, containing gigantic versions of the Earth's Van Allen Belts, which trap high-energy charged particles of mostly electrons and protons. There are also forces associated with the rapid rotation of Jupiter and because of these, along with the giant planet's magnetic field, these particles are flattened into plasma sheets. Jupiter's magnetic field rotates around once every nine hours. **GL**

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

Ancient astronomers built henges to line up with the position of the Sun

ASTRONOMY

Who were the earliest astronomers?

Brian Shane

The first recorded example of astronomy-like activity being conducted is around 3,500 years old and comes from Mesopotamia. Babylonian writings and star charts mapping out the sky, as well as making constant reference to the names of stars given to them by the Sumerians, suggest these people were probably observing the night sky back in the early Bronze Age. Confirmation of the earliest astronomers is tricky to pin down, as experts believe that people have always studied the sky in one way or another. Archaeologists have found solar observatories from 5,000 BCE built in central Europe. These henges were designed to line up with the position of the Sun and sometimes the Moon at various times of the year, usually the seasonal solstices. **JB**

SPACE EXPLORATION

What happens if an astronaut gets thirsty on a spacewalk?

Simon Isaacs

An astronaut's spacesuit is built to provide them with everything they need for the hours they will spend on a spacewalk, including water to drink if they are thirsty.

The technology used is quite simply a water-filled pouch that's mounted inside the upper torso section of the spacesuit. The bag has a tube that's fed up into the wearer's helmet and positioned close by the mouth. If an astronaut wants to take a drink, all they need to do is put the tube in their mouth and drink like you would through a straw. Unlike a straw on Earth, though, the tube must be fitted with a valve that only enables water to pass when someone bites on it. **ZB**

Spacesuits have a built-in supply of water for drinking on long spacewalks

Quick-fire questions

@spaceanswers

What exactly is a complex crater?

These are impacts in a rocky planet's surface with low depth-to-diameter ratios. This type of crater often has a central peak, trough and terraced rim structure.

Why are some stars brighter than others?

Not all stars are the same distance from us or the same type. How bright a star appears in the night sky depends on its size and how far away it is.

Can the LHC replicate the Big Bang?

The Large Hadron Collider (LHC) based in Geneva, Switzerland, is able to mimic the conditions that we believe to have existed a millionth of a second after the birth of the universe.

Can we fly on Titan?

It's said that, because of Titan's low gravity and thick atmosphere, if you were to strap on wings and flap your arms, you'd be able to fly through the atmosphere.

What are catadioptric telescopes for?

These telescopes combine the best features of refractors and reflectors in one single setup. Catadioptric telescopes have large apertures and long focal lengths for excellent performance.

What is the oldest planet that we know of?

PSR B1620-26 b, also nicknamed Methuselah and the Genesis planet, is believed to be 12.7 billion years old. The exoplanet, located 12,400 light years away in the constellation of Scorpius, was confirmed in 2003.

Are binoculars better than telescopes?

This depends on your budget, comparisons between the aperture and strength of the two, as well as what you're wanting to observe. A good pair of binoculars are better than a cheap telescope.

Quick-fire questions

@spaceanswers

Why does the ISS have an air conditioner?

The International Space Station's Sun-facing side heats anywhere up to 121°C (250°F). Combine this with the fact that it's packed with computers, gadgets and experiments that give off plenty of heat. Air conditioning keeps temperatures just right.

What colour can auroras be?

Auroras come in a variety of colours including reds, greens, purples as well as oranges.

What is the brightest star in the sky?

The Northern Hemisphere's Sirius is the brightest star in the sky and shines at a magnitude of -1.46

Why does Neptune appear blue?

Since methane in Neptune's upper atmosphere absorbs red light (or wavelengths) from the Sun, yet reflects blue light back into space, this ice giant appears blue.

What exactly is a supernova remnant?

Supernova remnants are the structures given off from the explosion of a star in a supernova. Famous examples are SN 1987A, the Crab nebula and Cassiopeia A.

How bright is the Milky Way's centre?

Some say the centre of the Milky Way shines with the brightness of 10 million Suns. However, since we're around 25,000 light years away from it and thick interstellar dust blots out its brightness, our galaxy's central region appears to be quite faint.

What is a black dwarf?

A black dwarf is a white dwarf that has cooled down so much that it becomes invisible. They are as yet only hypothetical.

Resting 63 light years from us, experts think that gas giant HD 189733b is a deep-blue world

DEEP SPACE

Can we work out an exoplanet's colour?

Thomas Davis

The difficulty with observing exoplanets is that they're so very small in comparison with their stars that we can't observe them directly. However, it's possible to calculate the colour of an exoplanet by watching as it moves behind its parent star. We call this a secondary eclipse and it temporarily blocks the light reflected off the planet from reaching us.

By recording the decrease in thermal radiation and light coming from the system before, during and after the event, we can get information about the type of world we're looking at. We can carefully analyse the changes in the light spectrum as the planet is hidden and observe which wavelengths of light go missing. From this we can deduce what colour the exoplanet should appear. **ZB**

Researchers think they could have found a Jupiter-like exoplanet with its own rocky moon

DEEP SPACE

Do exomoons exist?

Julian Banks

Given that several planets in our Solar System have moons, it's extremely likely that moons exist outside the Solar System too. In fact a team of astronomers may have recently found a potential exomoon in orbit around a distant gas giant.

The team used gravitational microlensing, which takes advantage of chance alignments between stars, to uncover the candidate. If one of these stars has a planet circling it, the alien world can act as a second lens to brighten or dim the light even more. The team are now wondering if they've actually found a moon, because they've uncovered a source of microlensing. However, as they're unlikely to see this effect again, figuring out whether they've made a discovery or not is going to be tricky. **GL**

A Herschel prism enables you to safely observe the Sun

ASTRONOMY

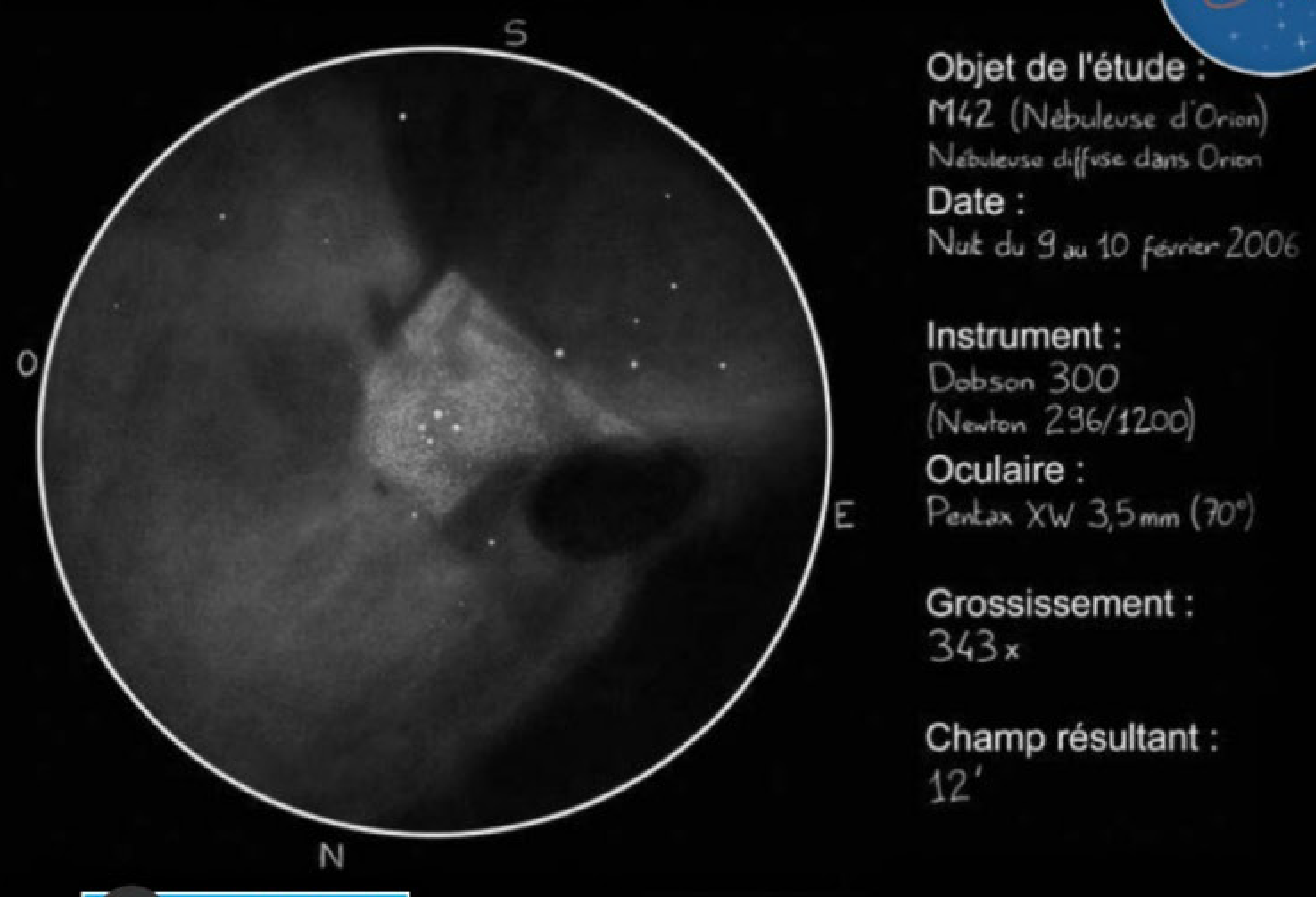
What is a Herschel prism?

Jenny Cox

A Herschel prism, also called a Herschel wedge, is an optical prism that's used by astronomers when making solar observations. Attaching these wedges to a telescope ensures safe viewing of our Sun. Remember, it's dangerous to look directly at the Sun without any protection.

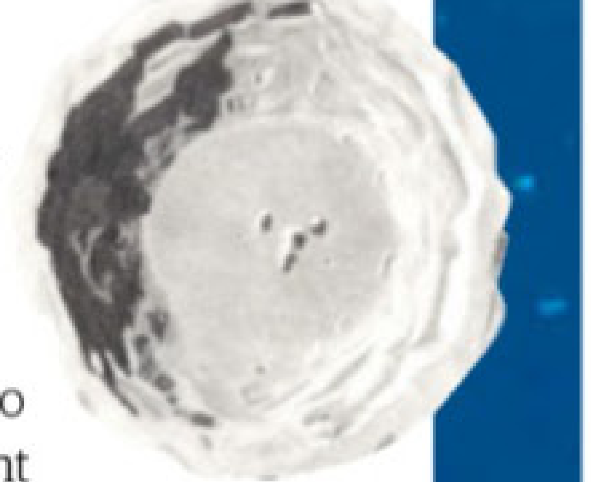
Originally proposed in the 1830s by astronomer John Herschel, this prism acts by refracting - or bending - blinding light rays out of the observer's optical path. The prism's surface works in the same way as a standard diagonal mirror, reflecting a small amount of incoming light into the eyepiece. The remaining light is then gathered by the prism's trapezoidal shape, directing it away from the astronomer's eye. **GL**

Sketching is a great, cheap alternative to astrophotography



ASTRONOMY

How can I get started in astro sketching?



Jon Bennett

Astro sketching is a cheap alternative to astrophotography and is relatively simple to pick up. The easiest way to start is to get yourself a pad of paper, as well as some pencils (of different gradients), before heading outside.

Of course, in order to add more detail to your sketches, you need to be able to see more detail, requiring additional hardware. A good start to any observing is a decent pair of binoculars, which are often better than equivalent telescopes. A free-standing device will free up your hands to draw, so a mount may also be a worthwhile investment. A good set of pencils is also recommended, as the varying grades will help with details in nebulas and galaxies. **JB**

Astronauts use Manned Maneuvering Units, which are effectively jet packs

SPACE EXPLORATION

Can we use jet packs in space?

David Massey

Yes! In fact the physics behind how a jet pack works is the same reason a rocket can get off the ground in the first place. According to Newton's Third Law, if you put a force on something, the object pushes back with an equal and opposite force.

As a result, if a rocket or jet pack throws particles resulting from the burning of fuels and oxygen behind them, those particles exert an equal and opposite force propelling them in the other direction. As long as a jet pack has a supply of fuel and oxygen, you can use it in space. In fact, astronauts do sometimes use Manned Maneuvering Units, which are effectively jet packs, to navigate the outside of the International Space Station. **SA**

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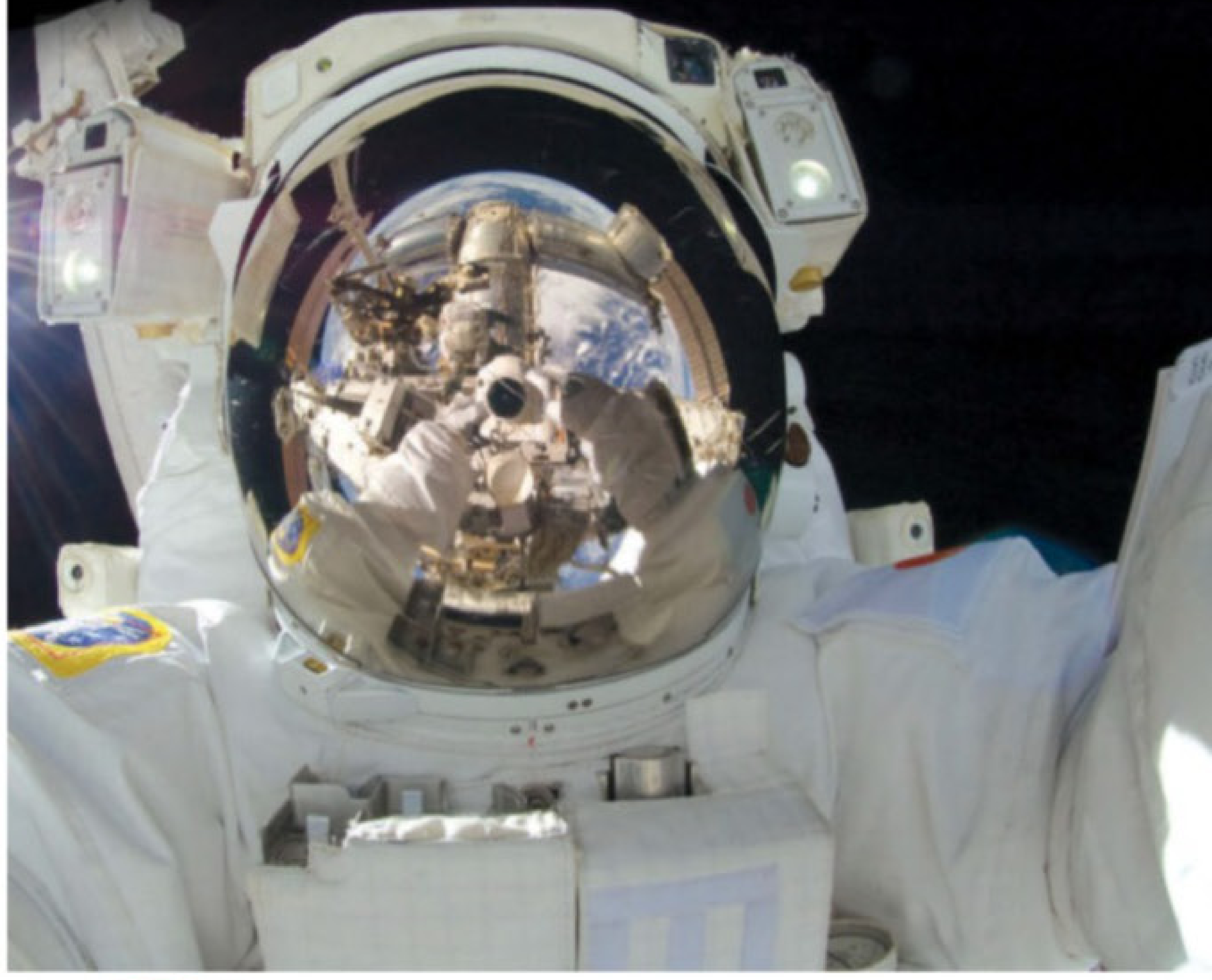
Plus five of the coolest jobs in space



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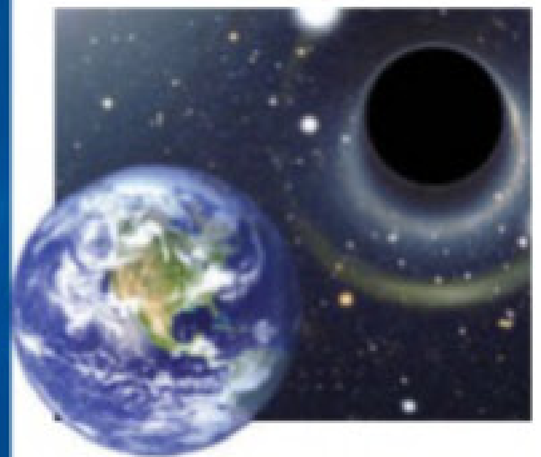
Follow the space-exploration roadmap to beyond the Solar System



EARTH'S NEAREST BLACK HOLE

All About Cygnus X-1, the most studied singularity in space

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Astrophotography for beginners

Learn the art of photographing the night sky with All About Space

The sky at night is one of the most awe-inspiring things to view and whenever a natural spectacle like this amazes us, one of the first urges is to capture an image of it. However, taking great photos of the night sky is harder than it looks. In fact, astrophotography may be more challenging than almost any other kind of photography.

As an astrophotographer striving to capture compelling images of the night sky, you need to build up your reserves of patience, be willing to drive for miles when you'd rather be tucked up in bed and be prepared to stay awake all night. Successful shoots will also need a large amount of planning and a good understanding of the equipment you're using. Then there's the science. Decent astronomical and meteorological knowledge is definitely an advantage that rapidly becomes a necessity if you want to take close-up portraits of the Moon and stunning images of distant celestial objects.

You can't take great shots of the heavens on any given night of the year, which is why one of the first virtues astrophotographers need is patience. For example, if there is any kind of cloud coverage, the stars will be obscured and great images are difficult to obtain, even with extensive equipment. This is one of the reasons why the stars often seem brighter on cold, winter nights. At these times the low temperature is in part due to an absence of cloud, enabling heat to escape from Earth and disperse into the atmosphere.

Another reason for the vivid sparkles of winter skies is that the Sun drops below the horizon by a much greater degree than in summer. Though it's almost imperceptible to the naked eye, during the height of summer there is some degree of sunlight interfering with the clarity of the night sky for all but a few hours. Unfortunately we are at the mercy of this weather, which cannot be predicted too far in advance.

However, not all of the challenges faced by astrophotographers come down to the raw science of astronomy and meteorology. Human activity also greatly affects the chances of obtaining a clear view of the canopy of stars. For example, the summer months can present an additional problem if smog, general air pollution, dust particles and exhaust fumes gather in the atmosphere during a period of prolonged high temperatures and poor airflow.

However, this isn't the only kind of pollution astrophotographers have to contend with. An even bigger problem is light pollution and it's the combined effects of these two pollutants that force those searching for the clearest views out into isolated and dark areas. It's this ongoing search for perfect conditions that often drives large-scale scientific observations hundreds of miles from the nearest major city.

The glow of several thousand lights burning all night long in the big cities affects the visual clarity of the starlight and also plays havoc with long camera exposures, presenting itself as an orange haze that competes for attention with the main attraction in the skies above. This is why, the darker your observing site is, the better your results will be when it comes to photographing the night sky.

Astrophotography might seem daunting, but after this short guide you'll be imaging the night sky in no time. We'll guide you through what equipment you'll need, how to prepare it and how to start taking great images of the night sky and the celestial treasures that it holds.

Know your equipment

Don't press the shutter-release button just yet! Here's a guide to the kit you'll need for your astrophotography adventure

There's nothing worse than being unprepared on your first venture into astrophotography. Whether you're picking a suitable dark site or choosing which equipment you need to take along, you're very likely to get frustrated without preparation. So, before you get trigger-happy with the shutter, ensure you're ready to turn your lens to the night sky.

CCD camera

One-shot colour types of CCD have red, blue and green filters built in, while monochromatic types only work in black and white. One-shot types need multiple images through each relevant filter before being composited together to get the finished result.

Tripod

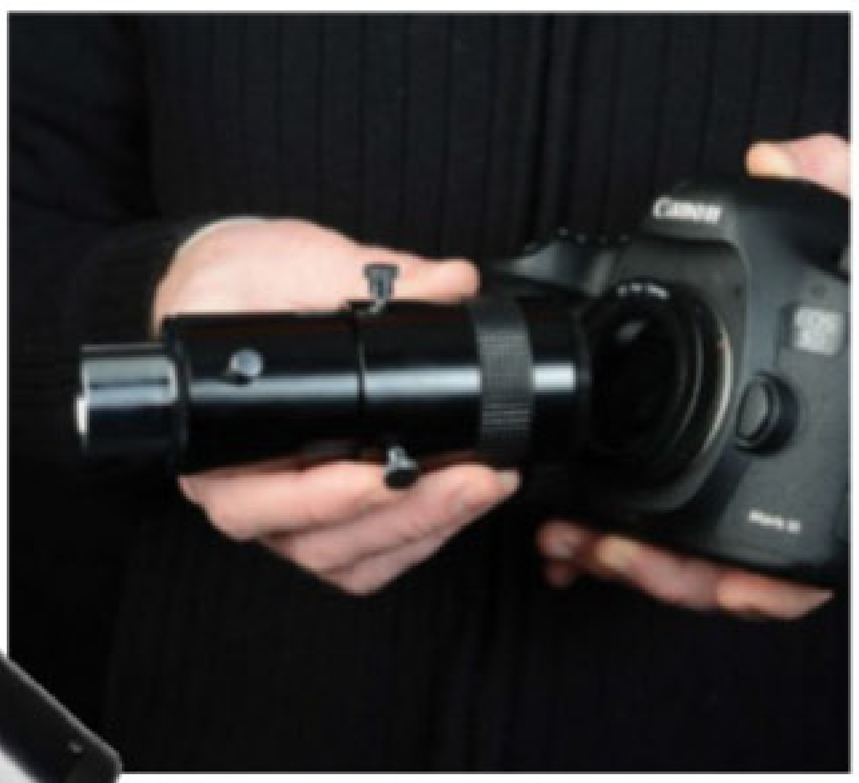
We will mostly associate tripods with telescopes, but if you're looking to take stable, wide-angle, long-exposure shots, fitting your DSLR camera to a tripod and a suitable mount is a must for great results.

Filters

Filters are available for various eyepiece sizes for a wide range of telescopes. You'll likely come across a variety of different filters - red, green, blue, yellow, polarising, H-alpha, H-beta, S-II and O-III. Some can also assist with cutting out light pollution. The idea of a filter is to play up features on planetary surfaces, as well as draw out the colours of nebulas and galaxies, picking out the colours that get lost when displayed through the eyepiece of your standard telescope.

Telescope

This is obviously the astronomer's main tool and while it's not essential for you to own one (if you're more into your wide-field nightscapes), it might be worth investing in one since it can offer much more in the way of astrophotography. When choosing your telescope, ensure it's able to support a camera - the quickest indicator is to look out for a counterbalance, often found on reflectors.



T-mount

A T-mount or adapter enables you to attach your camera to your telescope securely.

Software

Once you've taken your images, it's likely you'll need to manipulate them and truly bring out the features of the objects you've shot. For this you can use Photoshop or more-specialist software such as RegiStax.

DSLR camera

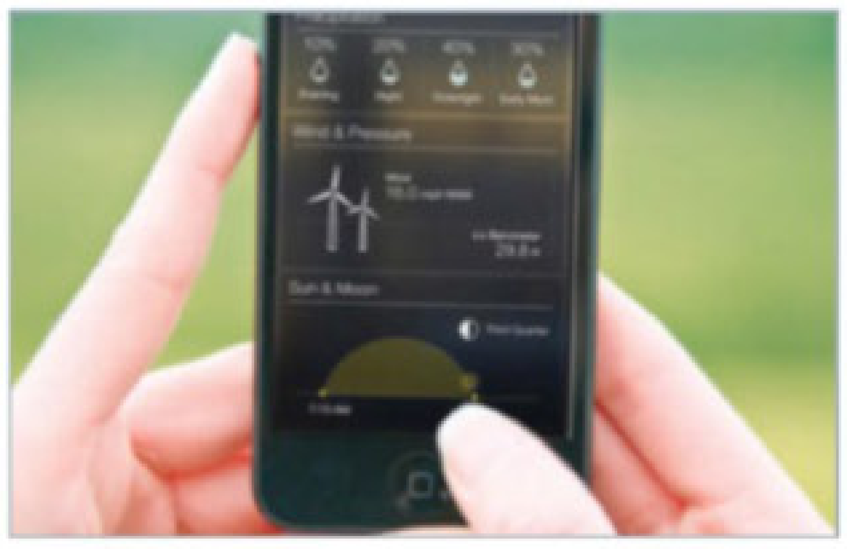
Digital SLR cameras are a great tool for astrophotography and are perfect for capturing star trails, dramatic Milky Way shots and other wide-field nightscapes. These cameras offer high resolutions even in low-light conditions and are also able to capture deep-sky objects.

Plan your shoot

13 °C | °F
Precipitation: 30%
Humidity: 57%
Wind: 3 mph

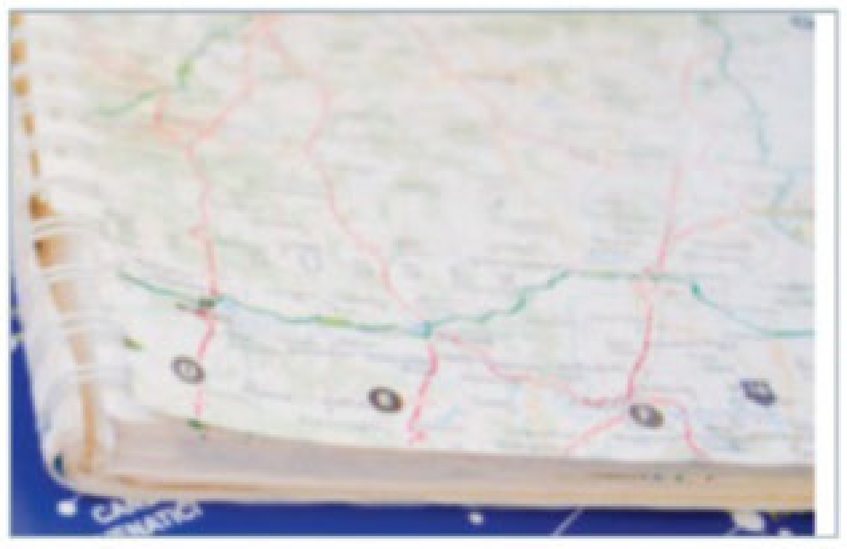
Check the weather

Keep a close eye on the weather if you're planning an overnight expedition. If cloud is predicted, you're likely to have an unsuccessful trip.



Take a mobile phone

As well as being useful for weather updates, a phone is essential if anything goes wrong - some of the best astronomy sites are lonely places.



Use a map

Study a map and familiarise yourself with your destination - don't just trust your sat nav to be able to guide you to some of the locations recommended.

Familiarise yourself

A simple star chart can be an excellent way of familiarising yourself with what the sky has to offer at each time of year.

You will need:

Capture stunning nightscapes

Shoot incredible night-sky shots with minimal equipment

We've all seen them – those stunning night-sky shots that show the world in motion in the form of star trails. These beautiful images are peppered with the stars of the Milky Way, as well as the eerie green glow of the northern lights snaking across the skies.

They may look immensely difficult to shoot, but the good news is that this part of astrophotography is perhaps the easiest. Not only that, but you only need the bare minimum kit and know-how to get decent results. Of course, you won't get perfect images to rival those of seasoned astrophotographers straight away, but with plenty of practise and patience you too could gradually get to their standard.

Many first-time astrophotographers struggle to achieve star-trail images. With the motion of our Earth continually at play it can often be difficult to figure out how to get a crisp shot. Additionally, and on the flip side of the coin, we have beginners wanting to stop the stars from moving so that they can image the rich star-filled Milky Way. To assist, **All About Space** has put together a guide for shooting in both instances.

Shoot the galaxy

How you can image the majesty of the Milky Way

Our galaxy is one of the most impressive sights in the night sky

Without question, the Milky Way is one of the most impressive views during an evening of observing, as it weaves its way majestically across the night sky. Since our Solar System is positioned in this galaxy, it's easy to think that we have the opportunity to see it every night, provided there's no light pollution and the skies are free of cloud, but this isn't the case.

The Milky Way is best observed and photographed throughout the summer months and especially in June, July and August. Since the nightly hours are shorter during the summer, the richest and unhindered views of our galaxy will be very limited.

When planning your shoot, you should aim to head out just after midnight for a good two to three hours. If you happen to be observing at a position closer to the Equator – such as southern Brazil, Queensland or South Africa – you'll often get the best sights and shots of our galaxy.

Get a star-packed image

Easy steps for great results

Set up

First ensure your camera is mounted on a solid tripod that's quick and easy to adjust. It should also be able to resist any wobbles caused by the wind and placed on flat, solid ground that's away from artificial light. Also avoid the natural light of the Moon and preferably shoot a few days before or after a new Moon.

Capture

In order to capture the Milky Way, you'll need to increase your camera's sensitivity. Ensure that you use a wide aperture, high ISO and shoot in RAW format to ensure quality. You may need to push your ISO up to 1600 or more to avoid long shutter speeds. To work out your shutter speed, divide 500 by your lens focal length.

Edit

You can sharpen up your images using Photoshop's Noise Reduction filter. If you have taken two separate exposures of the land and sky, just stack them together and use a layer mask and the Brush tool to blend the frames together. You can boost the colours and contrast by applying Curves and Color Balance tools.

Create a star-trail result

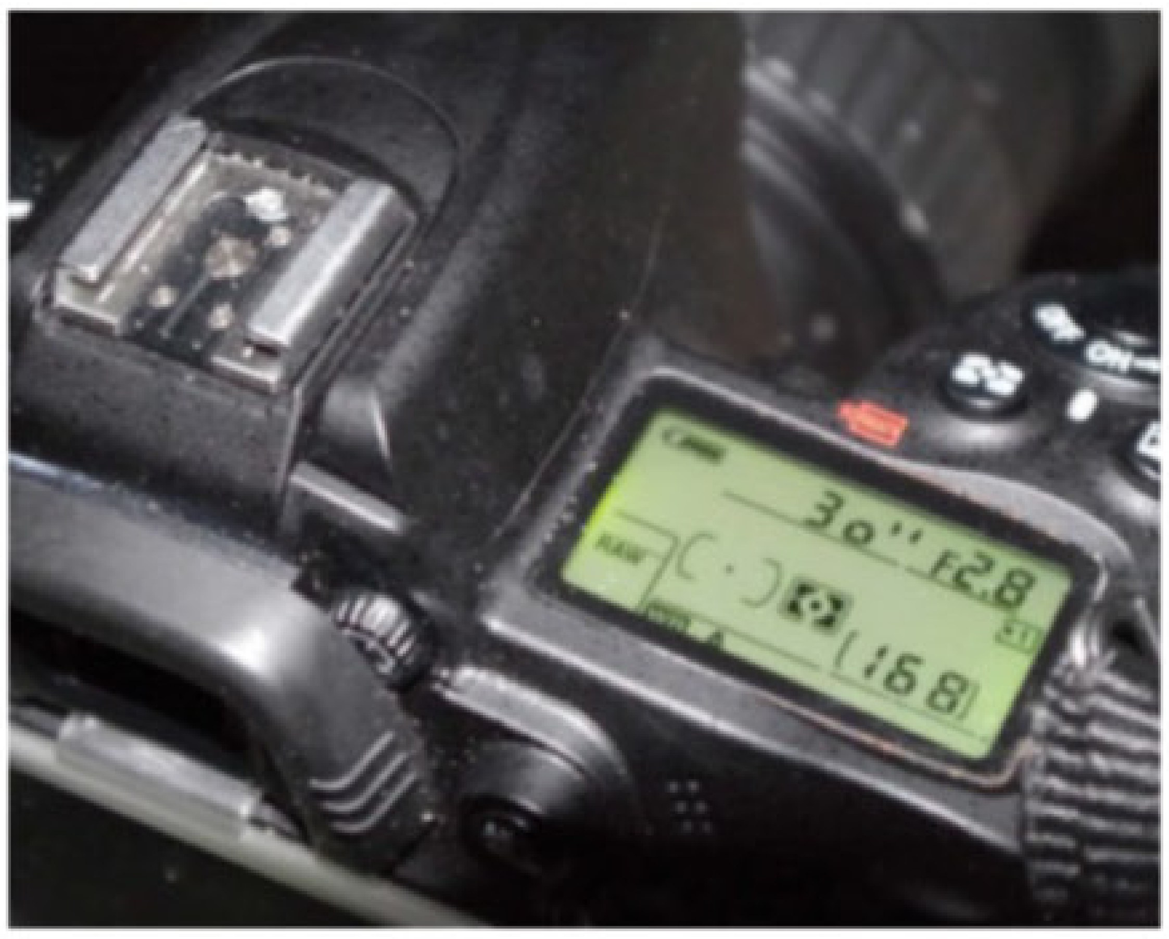
Capture the world in motion with these easy steps

There are two ways to capture star trails. The first is to take a long exposure of usually up to an hour and the second is to capture several shots of a few seconds each. You can then combine these shots in software that enables stacking, such as Photoshop.

This second approach is likely to leave you with superior image quality compared with leaving your camera on an hour-long exposure time. Here your star-trail image will be of poorer quality since DSLR sensors are prone to overheating with prolonged use.

1 Prepare your camera

Get your camera in the correct position for test shots, ensuring the north- (Polaris) or south-pole star (Sigma Octantis) is roughly at the centre.



2 Select the widest aperture

Set your camera to an aperture of around f/2.8 or whatever your camera's widest setting is. This boosts the light-gathering capabilities of the lens.

3 Set ISO and shutter speed

Once you've adjusted the camera's aperture, you'll need to set your camera to ISO 400 with a shutter speed of 30sec.

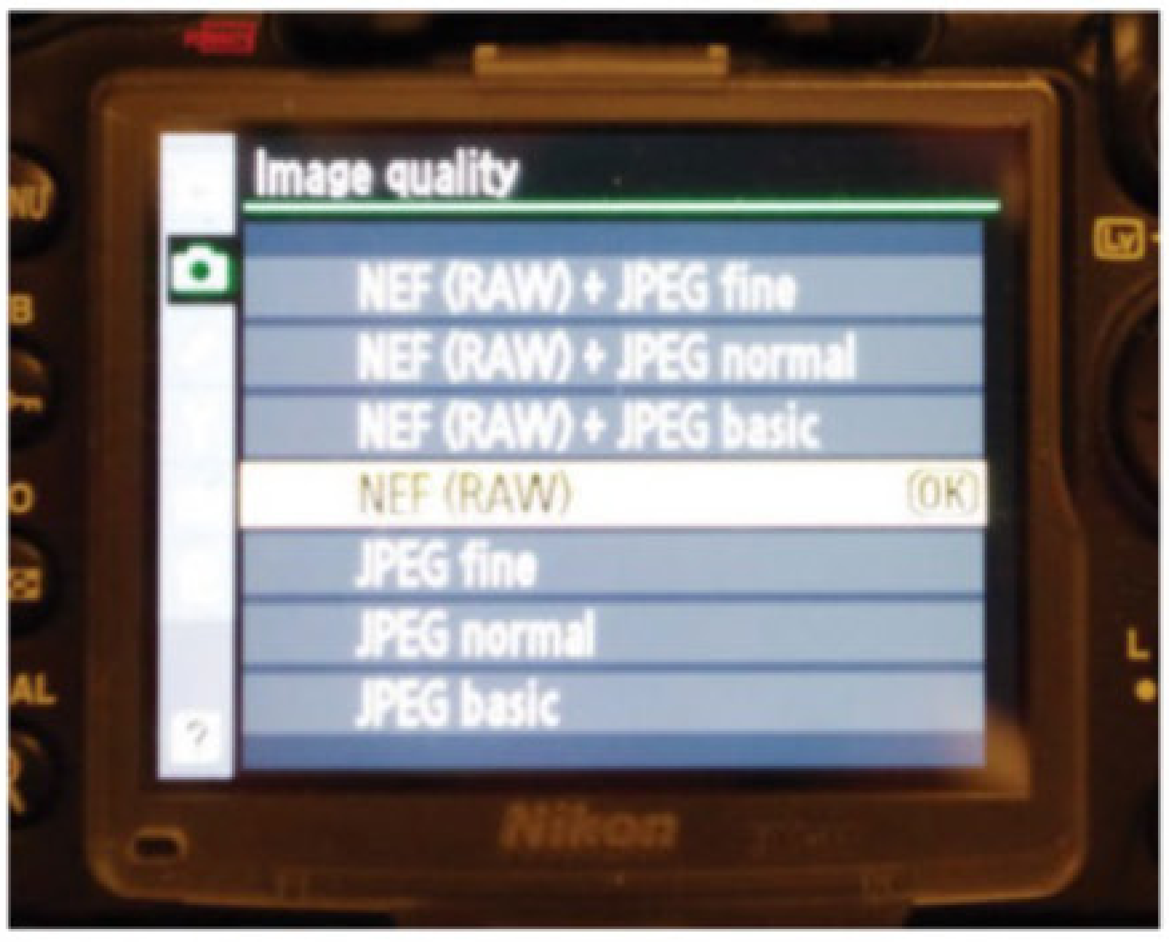


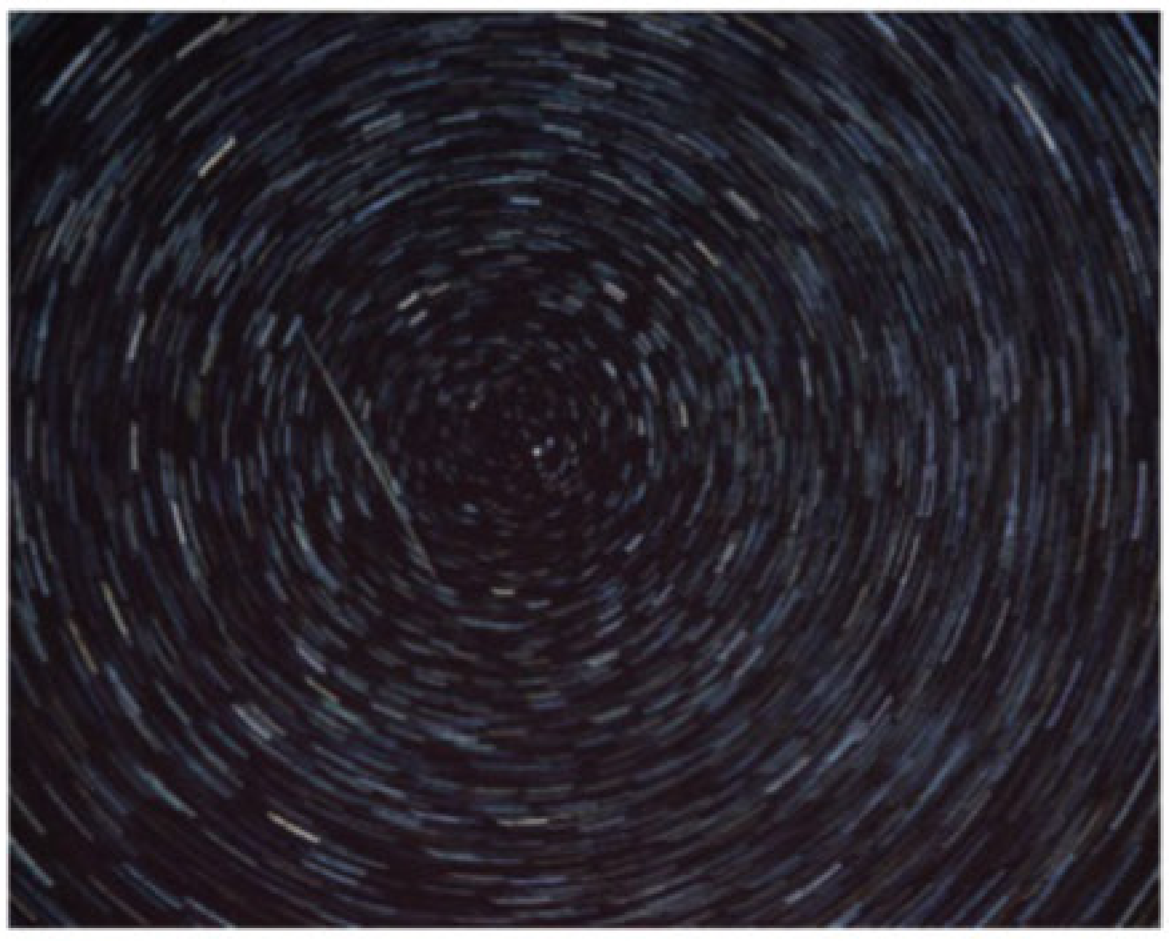
Image quality
NEF (RAW) + JPEG fine
NEF (RAW) + JPEG normal
NEF (RAW) + JPEG basic
NEF (RAW) (OK)
JPEG fine
JPEG normal
JPEG basic

4 Shoot in RAW

Snap 20 to 30 frames in RAW format for the best quality. When you process these files later, ensure that the same processing settings are applied.

5 Convert in post-production

In Photoshop, stack the frames as layers and convert all of them except the Background layer (your initial frame) to Lighten blending mode.



6 Finalise the result

Your star-trail image is now almost complete. All that remains is to flatten the layers by going to Layer>Flatten Image.

Pick the best spot

You might already have a location in mind where you're planning on kick-starting your astro-imaging. It may be your backyard is dark enough, or you might be heading over to farmland where you can escape the bright town or city lights.

If you're undecided, your best bet is to attend a dark-sky park or reserve. Here is our pick of the top dark-sky sites untouched by artificial light.

Sark

Location: Channel Islands
Area: 5.4km²/ 2.1mi²

Galloway Forest Park

Location: Dumfries & Galloway, Scotland
Area: 150km²/ 58mi²

Aoraki Mackenzie International Dark Sky Reserve

Location: South Island, New Zealand
Area: 4,300km²/ 1,660mi²

Northumberland National Park and Kielder Water Forest Park

Location: Northumberland, England
Area: 1,500km²/ 580mi²

Big Bend National Park

Location: Texas, USA
Area: 3,242km²/ 1,252mi²

Cherry Springs

Location: Pennsylvania, USA
Area: 0.5km²/ 0.18mi²

Nightscapes at a glance

Constellations

Exposure: 15-40sec
Aperture: f/2-f/2.8
Sensitivity: ISO 800-1600

Twilight landscapes

Exposure: 1-10sec
Aperture: f/2.8-f/5.6
Sensitivity: ISO 100

Auroras

Exposure: 3 to 30sec
Aperture: f/2-f/2.8
Sensitivity: ISO 400

The Moon in a few of its elegant lunar phases

Jupiter's famous spot is a favourite focus for many veteran astrophotographers

Saturn is another easily recognisable night-sky object to capture

You will need:

CCD

Shoot celestial bodies

Whether the Moon or planets are your target, here are the essentials you need to get the best outcome

Taking pictures of the Moon and bright planets isn't as difficult as you may think. Although you won't produce images as spectacular as the Hubble Space Telescope, with a little practise, patience and the right equipment, you'll be snapping portraits of lunar craters and the rings of Saturn in no time at all.

To shoot the Moon, for instance, you'll need a small telescope of between 4" and 6" aperture. You'll also need a DSLR camera and an adaptor to fix it to the telescope where the eyepiece would normally go. You can use the screen on the back of the camera to check you have the object in focus. Because the Moon moves quite fast across the sky, you'll find it keeps moving out of the field of view. If you have a motorised telescope you can track it, otherwise you'll keep having to make adjustments.

As far as camera settings go, because the Moon is so bright you'll only need to use an ISO setting of around 300. Experiment with the length of exposure to see what works best, checking your results and adjusting. Don't expose the camera for too long or you'll overexpose the brightest parts of the Moon.

While DSLRs are ideal for imaging the Moon, webcams and CCDs are better for photographing the planets, as these are much smaller in the sky and not as bright. The best planets to capture are Mars, Jupiter and Saturn when they are at their optimal size and brightness in the sky. Mercury is too small and too close to the Sun, while Venus is fairly dull to image thanks to its cloudy atmosphere. Uranus, Neptune and Pluto are too small and faint to take good pictures.

Webcams are useful because they enable the imager to create video files to take and combine as many of the best frames as possible. This is called stacking and you can download free software to do this, such as RegiStax. Exposure times are short too, just tenths of a second, but because you're going to stack the images they easily build up. The larger the telescope you have, the better, to be able to see details such as dark regions on Mars, the belts of Jupiter's atmosphere or the rings of Saturn.

Use a Barlow lens to help increase the magnification. If you're using a monochrome CCD, you'll also need to use colour filters in a filterwheel, which will produce image frames through either red, green or blue. You can then combine these in Photoshop to produce a final colour image.

The basics of night-sky shoots

If you don't have a DSLR camera, which can be expensive, don't worry! It's possible to take a good picture of the Moon through a telescope with just a compact camera or even the camera on your mobile phone. All you need is a telescope and a steady hand to take the shot.

Hold the camera up to the telescope eyepiece, zoom in and start snapping. You might find your first attempts are horribly blurred. If you're using a camera phone there are actually special holders that attach to your telescope that can hold your phone in place while you take the picture. Storage space greater than five megabytes is now common on many phones.

You will need: CCD

Bring the deep sky to you

Further afield there are galaxies and nebulas galore – perfect subjects for astrophotography

Imaging deep-sky objects such as nebulae and galaxies is a little different to bright planets and the Moon. Because these objects are fainter, you'll need much longer exposures. Some of the most dedicated deep-sky photographers take exposures that last hours, or even days!

First, take flat fields and dark frames. Many deep-sky objects are so faint that any noise in the image can ruin the photo. For example, dust on the telescope or the camera sensor can look like huge blemishes in images. By taking a picture of a blank background and then subtracting this from your astro images in Photoshop, it'll remove the dust effect. Meanwhile, dark frames use a similar trick to remove thermal noise produced by your camera. Taking an exposure with the camera shutter closed will create a dark image containing only the thermal noise, which can then be removed.

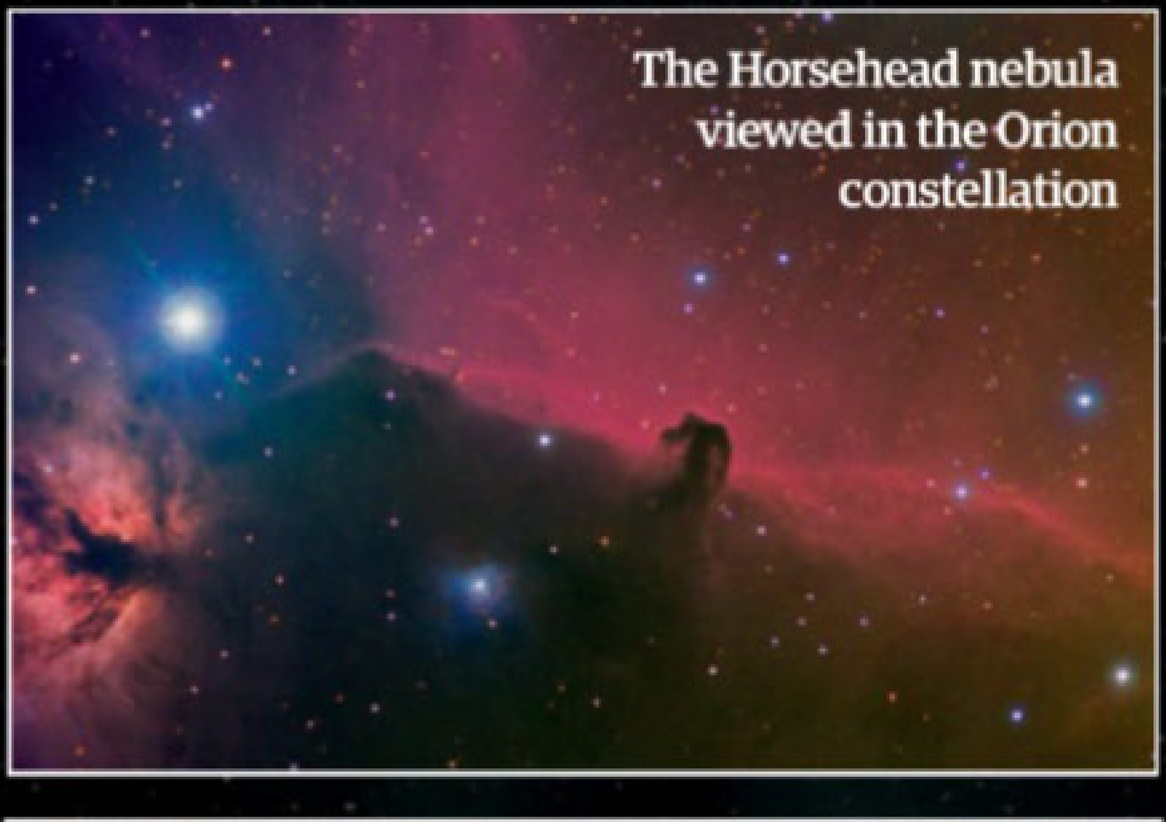
To take a picture of the Ring nebula M57, which is one of the most famous nebulae in summer skies, you'll need a large telescope of up to 200mm aperture. Schmidt-Cassegrain telescopes are useful for imaging because they have a long focal length and a small f-ratio, making them great for narrower fields of view so your nebula isn't a tiny fuzzy object hanging in a huge expanse of space.

Because you'll want to take long exposures, the sky will be turning over your head as you do so, which means the object will move and your telescope needs to keep up with it. Make sure you have a good motorised telescope mount, but more importantly an autoguider. This can fix to the finderscope on your telescope and contains a little CCD camera to keep track of the object.

You may also want to think about using filters and a monochrome camera. If you have a one-shot colour camera that collects light of all colours at once, it'll speed up the imaging process and is probably best for beginners. Dropping in a different filter, such as hydrogen-alpha or oxygen III will collect light emitted by, for example, the many ionised oxygen atoms in the nebula.

Spiral galaxies are more complicated to image because they have bright centres and fainter arms. Brighter areas need shorter exposures, while the fainter arms need longer exposures, so it seems obvious you can't successfully image both at the same time. The trick is to take shorter exposures for the centre first, then take longer exposures for the spiral arms. The centre will be overexposed but by masking the centre in Photoshop, then combining with the shorter exposures that just show the centre, you can get the best of both worlds.

The Orion nebula is yet another favourite object among astronomers


The Horsehead nebula viewed in the Orion constellation

Long exposures and filters can produce amazing results

DSLRs vs CCDs

CCDS

- 👍 Have less thermal noise
- 👍 Get more detail from fainter objects due to cooling
- 👍 Enable mosaics to be made
- 👍 Detects infrared light
- 👎 Cannot be used as an everyday camera

DSLR

- 👍 Useful for everyday photography as well as astro-imaging
- 👍 Don't require additional filters – they are one-shot colour cameras
- 👍 Take images with large field of view
- 👍 Cheaper than CCDs
- 👎 Large sensors often leave stars distorted towards edges of frame

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What's in the sky?

Darkness is fleeting in the Northern Hemisphere's summer, but there's still plenty to see if you're prepared to stay up late

Globular star cluster M10

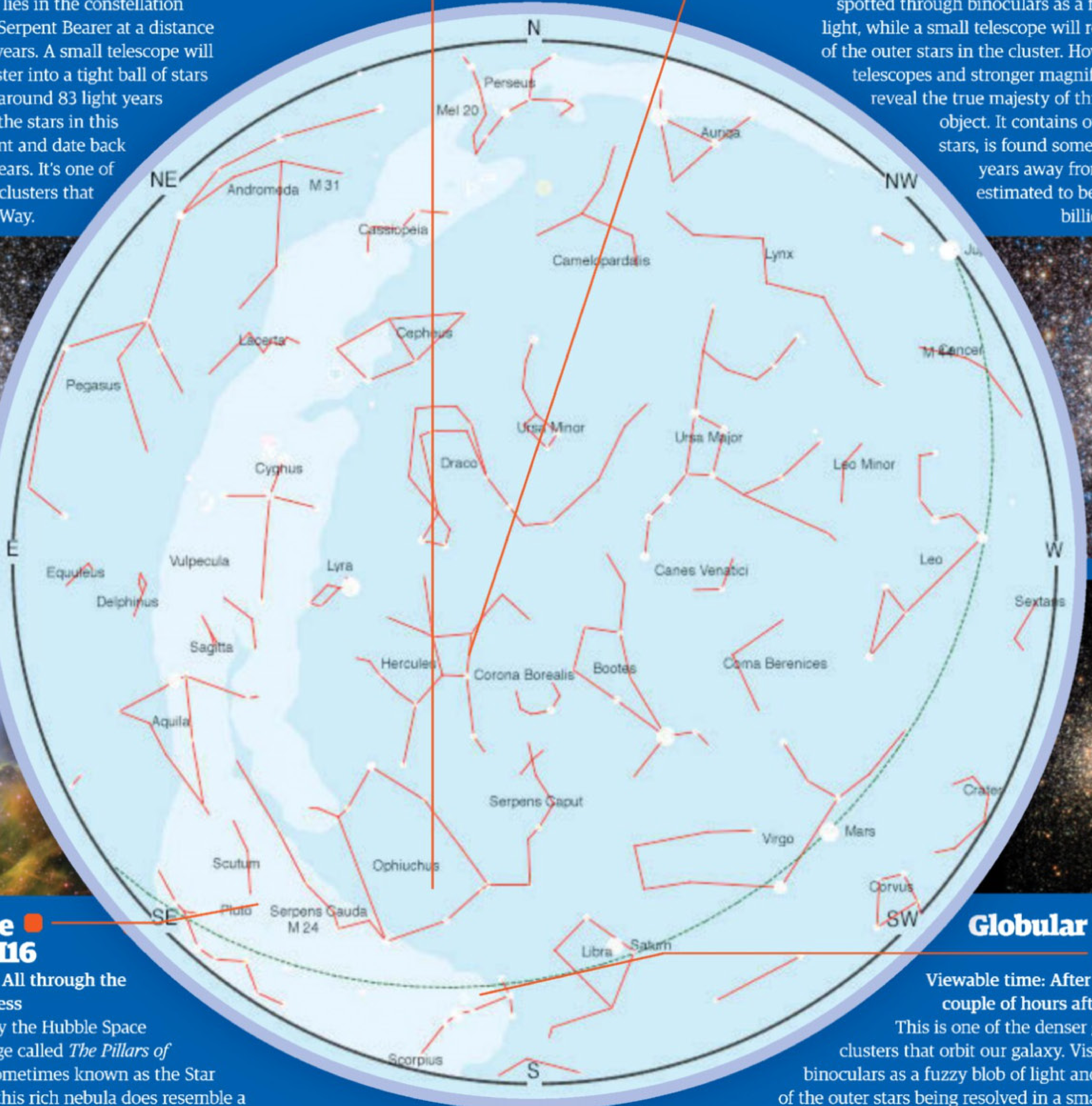
Viewable time: All through the hours of darkness

Easily visible through binoculars, this globular cluster lies in the constellation Ophiuchus the Serpent Bearer at a distance of 14,300 light years. A small telescope will resolve this cluster into a tight ball of stars reckoned to be around 83 light years across. Most of the stars in this group are ancient and date back over 11 billion years. It's one of dozens of such clusters that orbit the Milky Way.

Globular star cluster M13

Viewable time: All through the hours of darkness

The Great Cluster in Hercules is the brightest such object in the Northern Hemisphere. It's easily spotted through binoculars as a fuzzy blob of light, while a small telescope will resolve many of the outer stars in the cluster. However, larger telescopes and stronger magnifications will reveal the true majesty of this wonderful object. It contains over 300,000 stars, is found some 25,100 light years away from us and it's estimated to be around 11.6 billion years old.



Northern Hemisphere

The Eagle nebula M16

Viewable time: All through the hours of darkness

Made famous by the Hubble Space telescope's image called *The Pillars of Creation*, and sometimes known as the Star Queen nebula, this rich nebula does resemble a flying eagle when viewed through a telescope and in long-exposure images. It's also easily visible through binoculars. It contains several active star-forming regions and sits around 7,000 light years away. Nebula filters help enhance the view through a telescope.

Globular cluster M80

Viewable time: After dark until a couple of hours after midnight

This is one of the denser globular star clusters that orbit our galaxy. Visible through binoculars as a fuzzy blob of light and with many of the outer stars being resolved in a small telescope, this lovely globular cluster is well worth a look. It lies at an estimated distance of 32,600 light years from Earth and is thought to be around 95 light years across. It contains several hundred thousand stars and was catalogued by Charles Messier in 1781.

Open cluster NGC 6025

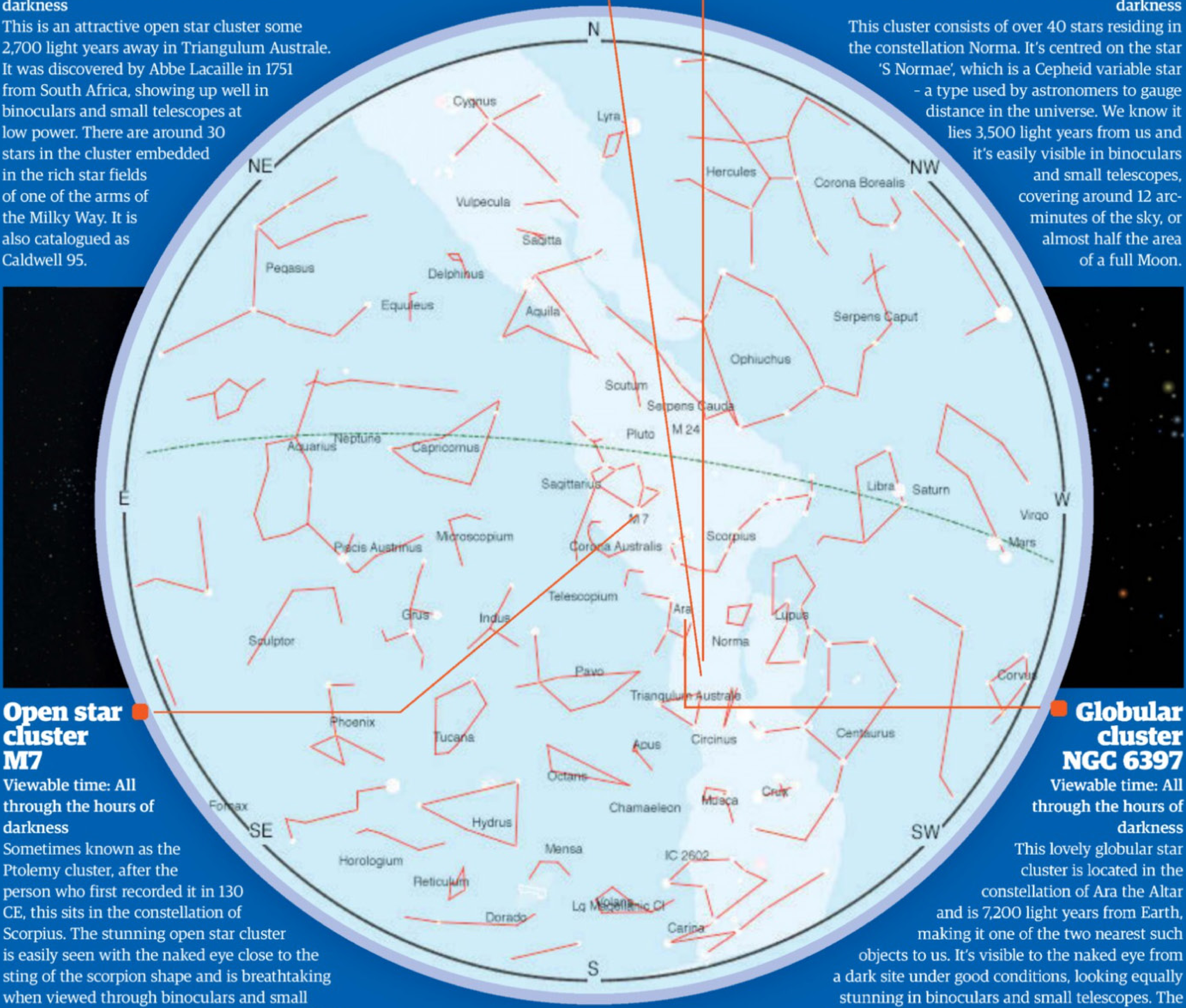
Viewable time: All through the hours of darkness

This is an attractive open star cluster some 2,700 light years away in Triangulum Australe. It was discovered by Abbe Lacaille in 1751 from South Africa, showing up well in binoculars and small telescopes at low power. There are around 30 stars in the cluster embedded in the rich star fields of one of the arms of the Milky Way. It is also catalogued as Caldwell 95.

Open star cluster NGC 6087

Viewable time: All through the hours of darkness

This cluster consists of over 40 stars residing in the constellation Norma. It's centred on the star 'S Normae', which is a Cepheid variable star – a type used by astronomers to gauge distance in the universe. We know it lies 3,500 light years from us and it's easily visible in binoculars and small telescopes, covering around 12 arc-minutes of the sky, or almost half the area of a full Moon.



Open star cluster M7

Viewable time: All through the hours of darkness

Sometimes known as the Ptolemy cluster, after the person who first recorded it in 130 CE, this sits in the constellation of Scorpius. The stunning open star cluster is easily seen with the naked eye close to the sting of the scorpion shape and is breathtaking when viewed through binoculars and small telescopes. There are around 80 stars in the group strewn across a field of 1.3 degrees in diameter, or over twice the diameter of the full Moon.

Globular cluster NGC 6397

Viewable time: All through the hours of darkness

This lovely globular star cluster is located in the constellation of Ara the Altar and is 7,200 light years from Earth, making it one of the two nearest such objects to us. It's visible to the naked eye from a dark site under good conditions, looking equally stunning in binoculars and small telescopes. The cluster is thought to contain around 400,000 stars and is 13.4 billion years old – among the oldest objects in the known universe.

Southern Hemisphere

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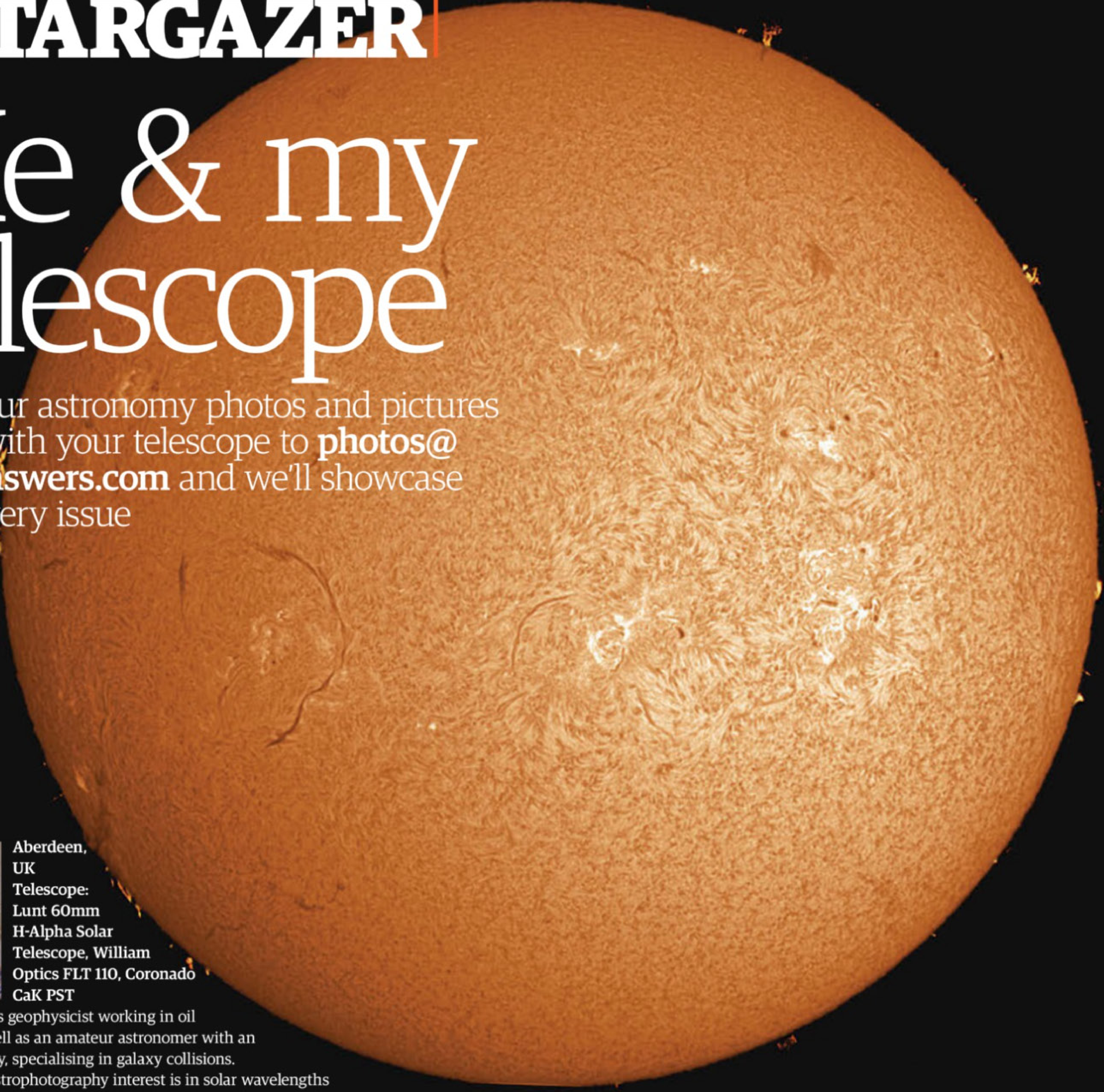
Me & my telescope

Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue



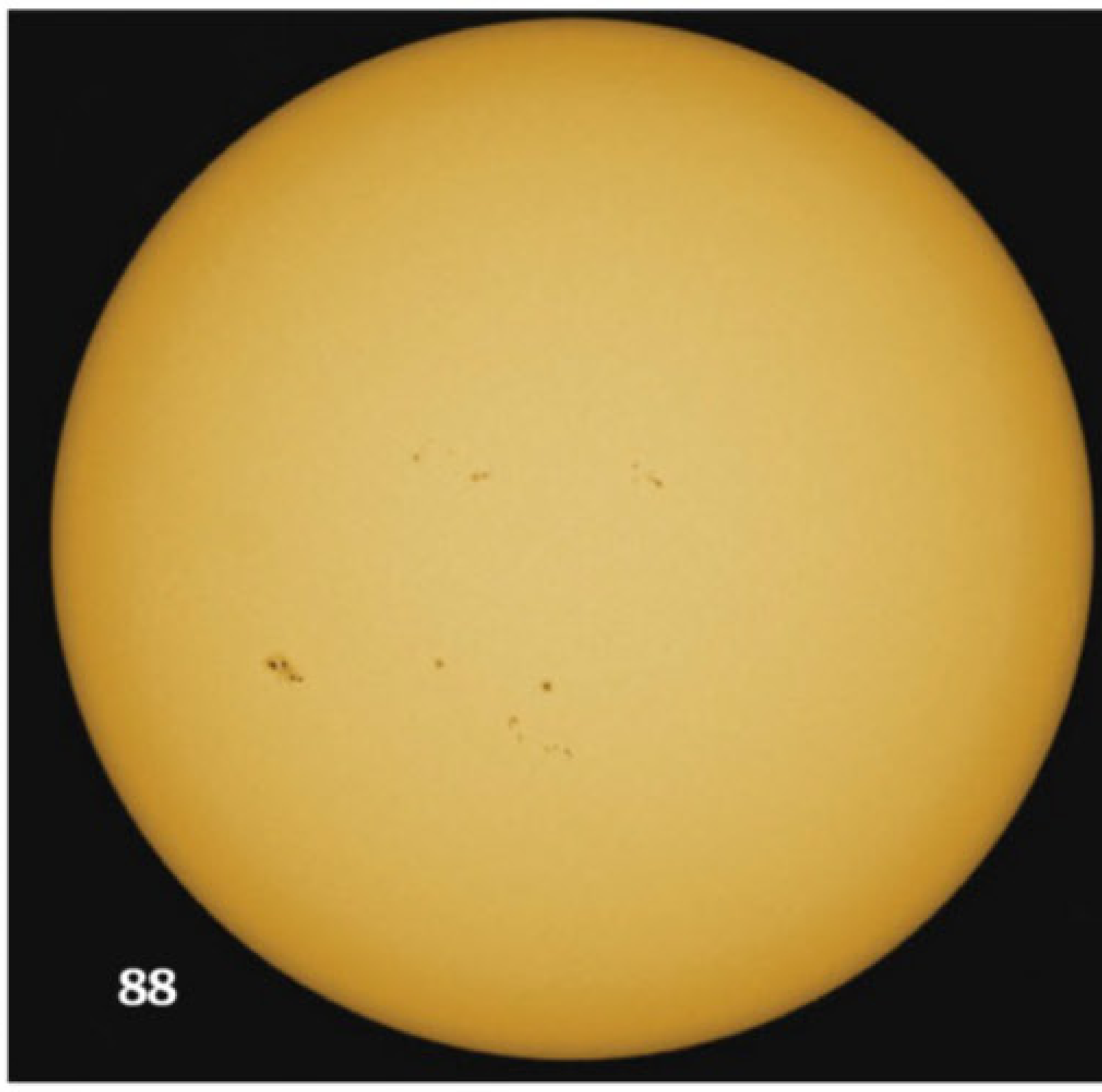
Sheri Lynn Karl

Aberdeen, UK

Telescope: Lunt 60mm H-Alpha Solar Telescope, William Optics FLT 110, Coronado CaK PST

"I'm an operations geophysicist working in oil exploration, as well as an amateur astronomer with an MSc in Astronomy, specialising in galaxy collisions.

"My primary astrophotography interest is in solar wavelengths of H-Alpha, CaK and white light... I used a SKYnyx 2.1 camera along with a Lunt 60mm, CaK PST and William Optics FLT 110 to take these solar shots."



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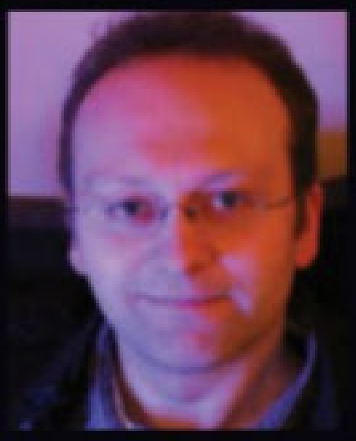
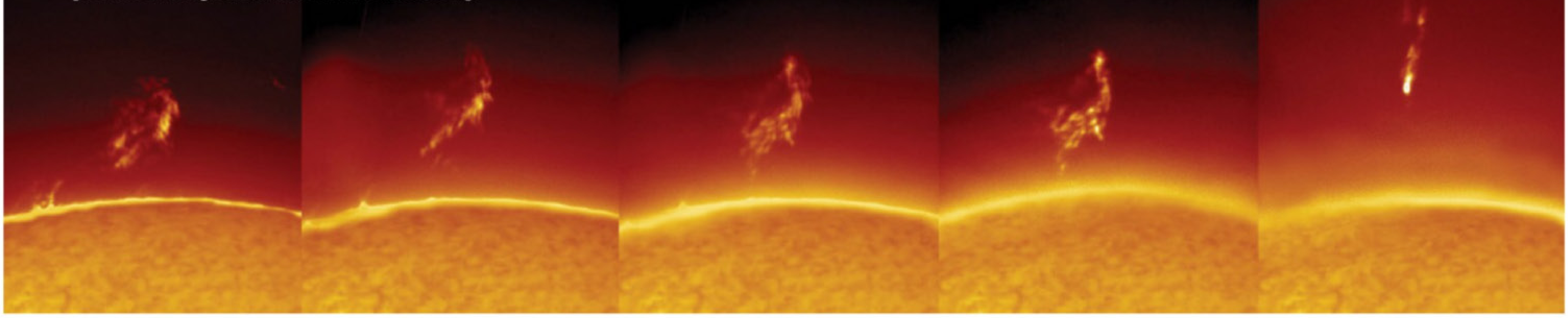
Stuart Hilliker



West Sussex, UK
Telescope: Meade 8" SCT, Pentax 75 Refractor, Coronado PST

"I became interested in astronomy at the age of ten, when my dad bought me a small handheld telescope. My first view of Saturn shortly afterwards was a revelation!

"My main telescopes are currently a Meade 8" SCT, Pentax 75 refractor and a Coronado PST. All are mounted on a Sky-Watcher EQ6. The solar photographs were taken using a ZWO ASI 120mm camera and Tele Vue 2X Powermate. They were processed using Autostakkert! 2 and Photoshop."

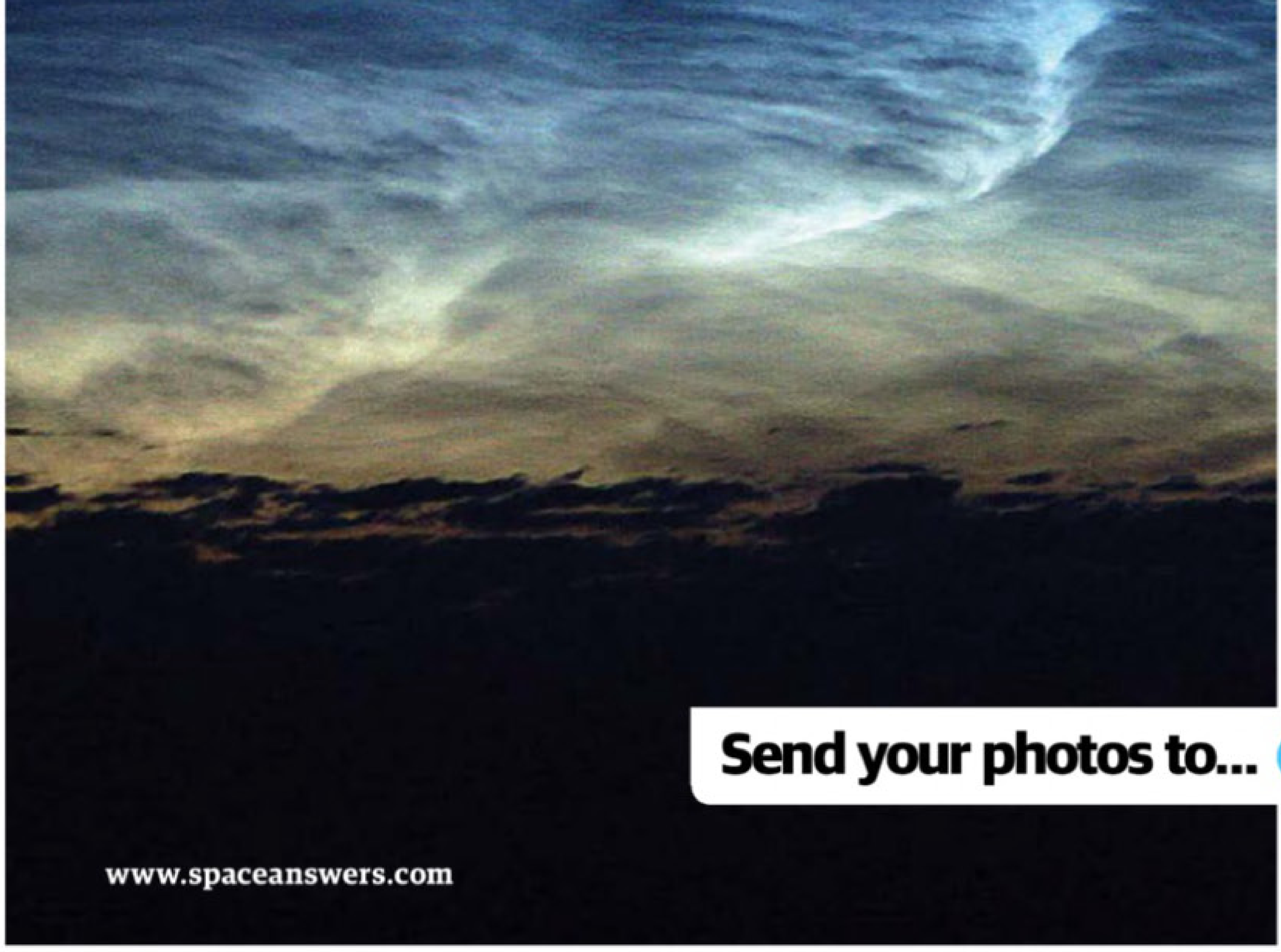


Stuart Atkinson

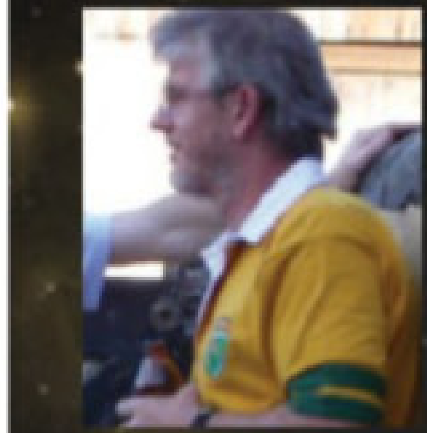
Cumbria, UK
Telescope: N/A

"My images of the noctilucent clouds were taken with a digital SLR camera on a tripod with some finishing touches achieved in image-processing programs.

"I am the secretary of the Eddington Astronomical Society of Kendal in Cumbria and have been taking astrophotographs since I was knee-high to R2-D2. I'm also very active in astronomy outreach and have given hundreds of illustrated lectures about astronomy and space to hundreds of people."



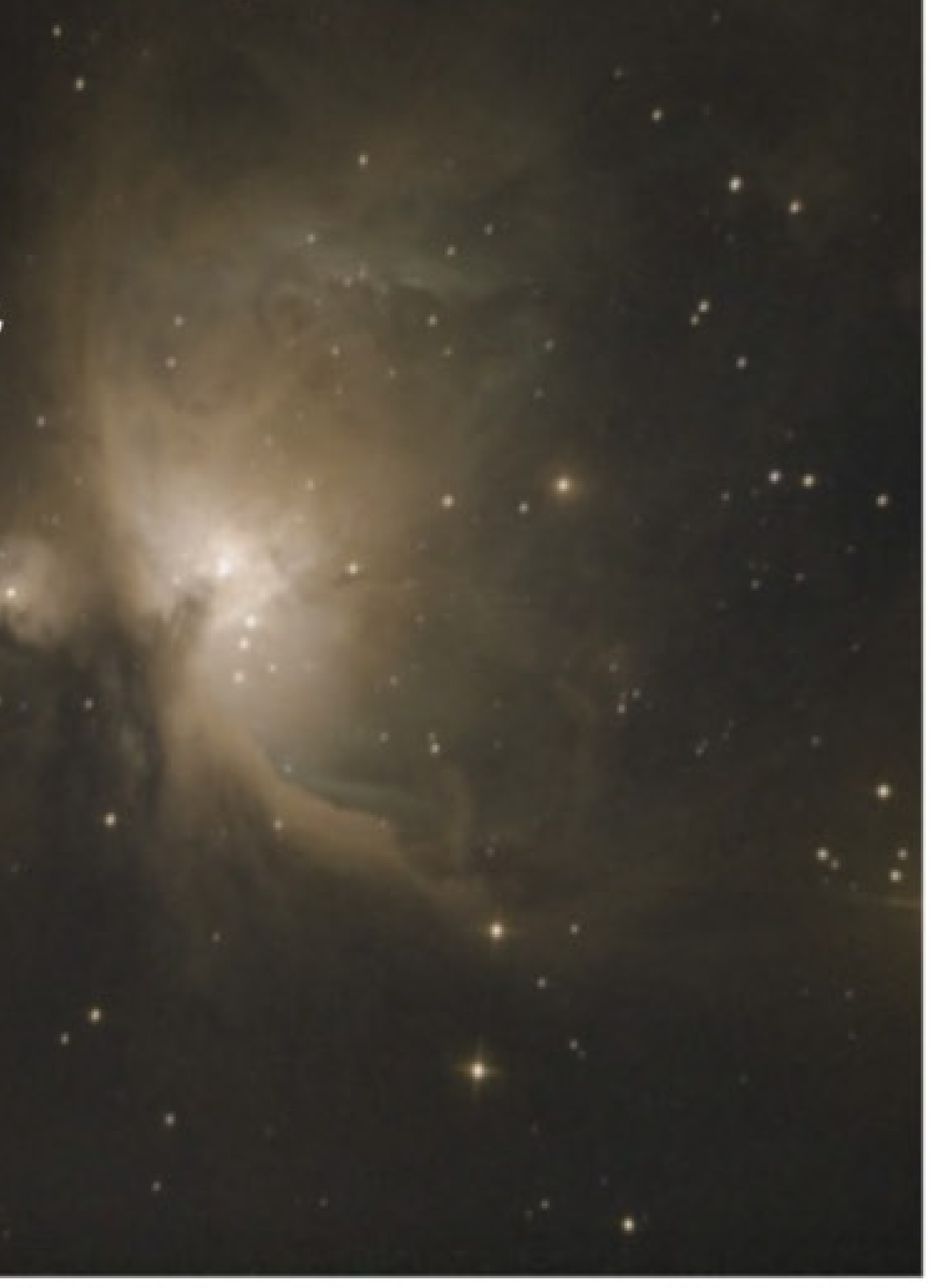
Scott Prideaux



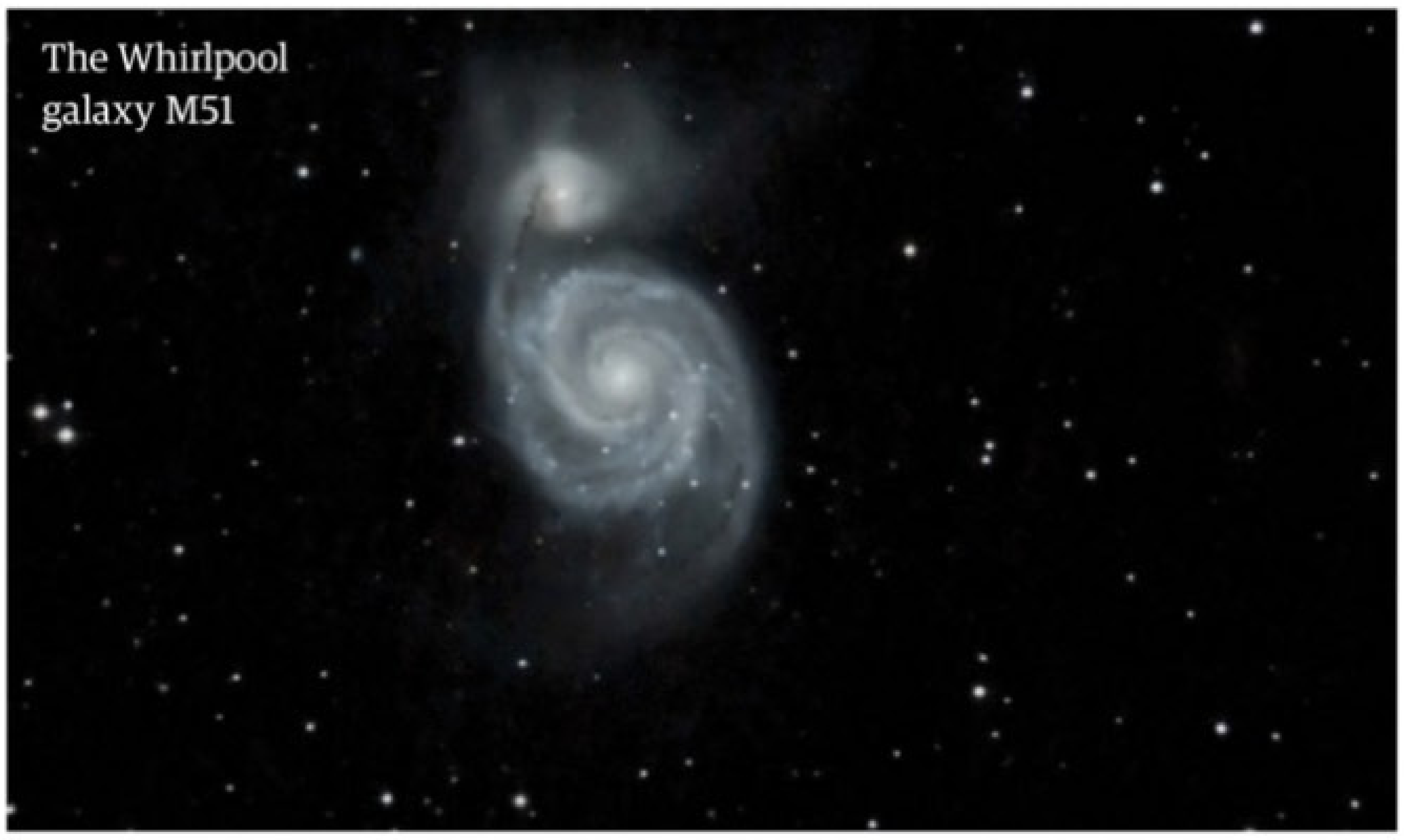
Stoke-on-Trent, UK
Telescope: Sky-Watcher Explorer 200P, Altair Astro Lightwave 60mm ED Triplet

"I've always had a mild interest in astronomy, however it wasn't until quite recently that I found myself becoming quite passionate about it...

"The image of M42, the Orion nebula, was around 50x 60sec subs and darks at ISO 800. Although not traditionally processed, I just thought the bronze look suited it."



Orion nebula M42



The Whirlpool galaxy M51

Send your photos to... @spaceanswers @ photos@spaceanswers.com

Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

Chris Lee

Location: Bristol, UK
Twitter: @cpl43uk
Info: Astronomer for over 40 years
Current rig
telescope: NexStar 8SE
Mount: Celestron AVX
Other: Hyperion Zoom lens, Williams Optics Binoviewer

"I have been enthralled by the night sky since boyhood and I even studied the subject to degree level. I'm an amateur sketcher, believing that drawing what you see at the eyepiece offers an excellent way to appreciate it.

"While I have a knowledge of the northern skies, I am a complete novice when it comes to the Southern Hemisphere. I was therefore thrilled recently to be able to extend a business meeting in Santiago, Chile, with a trip to San Pedro in the Atacama desert.

"The Atacama desert offers perhaps the darkest skies in the world and also one of the driest - an astronomer's dream! I had planned to book myself on a tourist star party, but unfortunately arrived too late for this on my first day. Instead, I immediately headed out into the desert with only my 10x50 binoculars and a sketch pad for company.

"The Milky Way stretched right across the sky and the Large Magellanic Cloud was so sharp I felt I could reach out and touch it! Stars that I had long observed from home took up new positions - Orion was on its side and Sirius was above it - as well as new constellations such as the iconic Crux - the Southern Cross. The Coalsack nebula looked like a black ink spot in a way I hadn't imagined.

"I sketched Omega Centauri and the Eta Carinae nebulae region and was looking forward to seeing these through a telescope. The next day I visited the nearby ALMA observatory but as early evening approached I could see ominous clouds gathering on the horizon. Sure enough it actually started raining in San Pedro! The tour party was postponed to the following day but sadly I was departing for home at first light. Astronomy can certainly be a most frustrating hobby!" ●

Chris's top three tips

1. Buy a pair of binoculars first

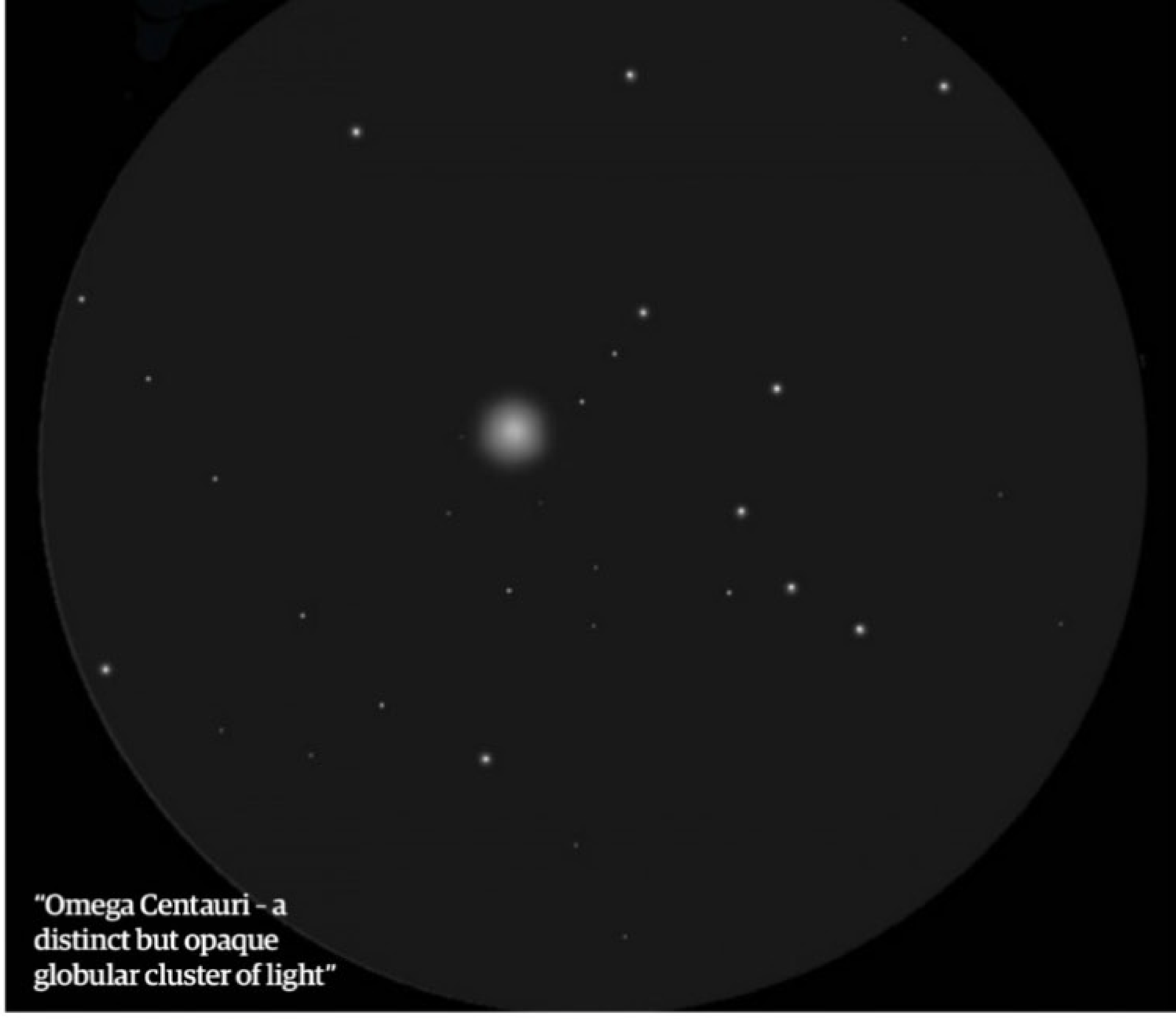
Learn your way around the night sky with a star atlas and/or a tablet app. Small telescopes can disappoint if you don't know what to expect.

2. Record your observations

Track observations in a log book and include a sketch! Tick off Messier objects or some similar list - this gives shape to your observing sessions.

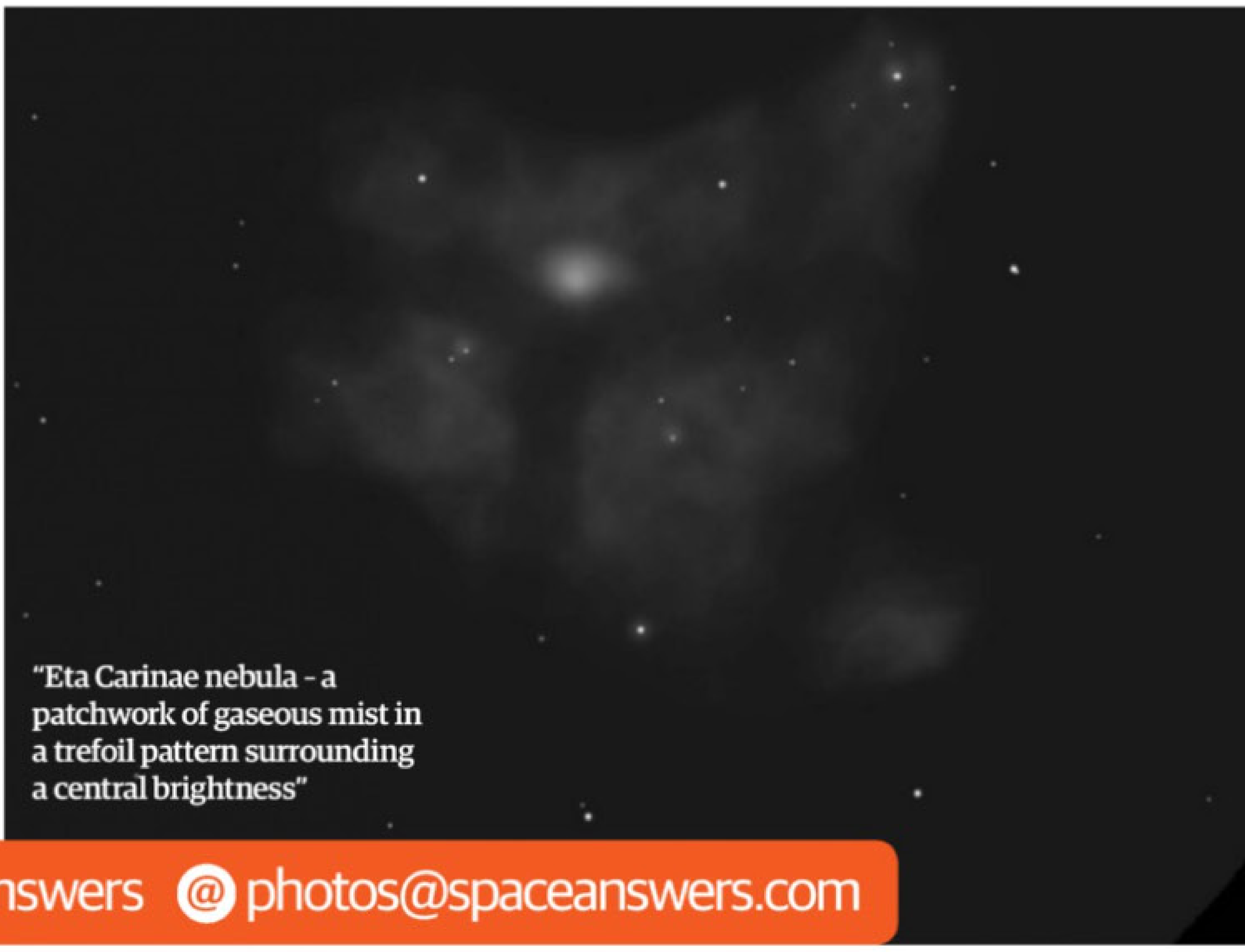
3. Join your local astro society

It's always good to meet fellow enthusiasts and share tips with one another. Personally I belong to Bristol Astronomical Society.



"Omega Centauri - a distinct but opaque globular cluster of light"

Chris' NexStar 8SE plus Celestron AVX mount



"Eta Carinae nebula - a patchwork of gaseous mist in a trefoil pattern surrounding a central brightness"

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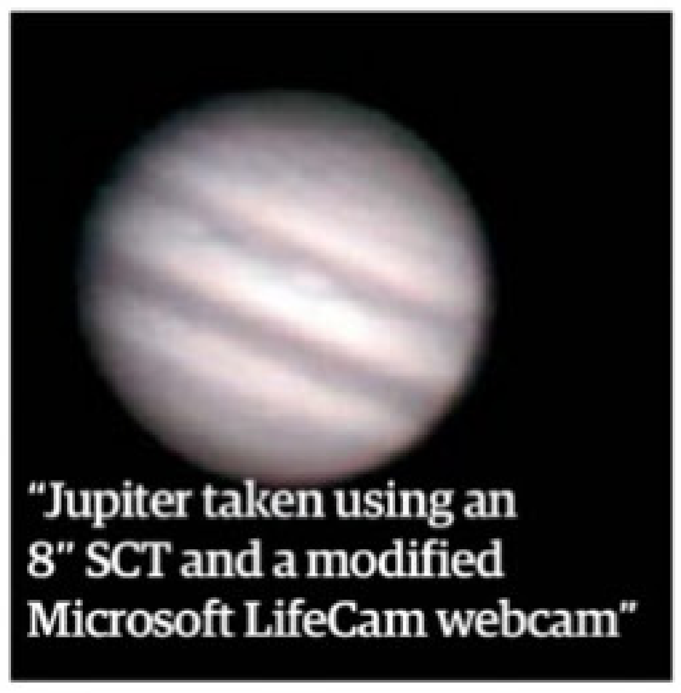
"Me with my weapon of choice (well almost) - a Meade Lx10 Schmidt-Cassegrain telescope.



"Jupiter taken using an 8" SCT and a modified Microsoft LifeCam webcam"

Alastair Leith

Location: Northampton, UK
Twitter: @OASoc
Info: Astronomer for 28 years
Current rig
Telescope: Meade LX10 8" f/10
Mount: Fork
Other: Personal Solar Telescope, Microsoft LifeCam, Star Analyser 100

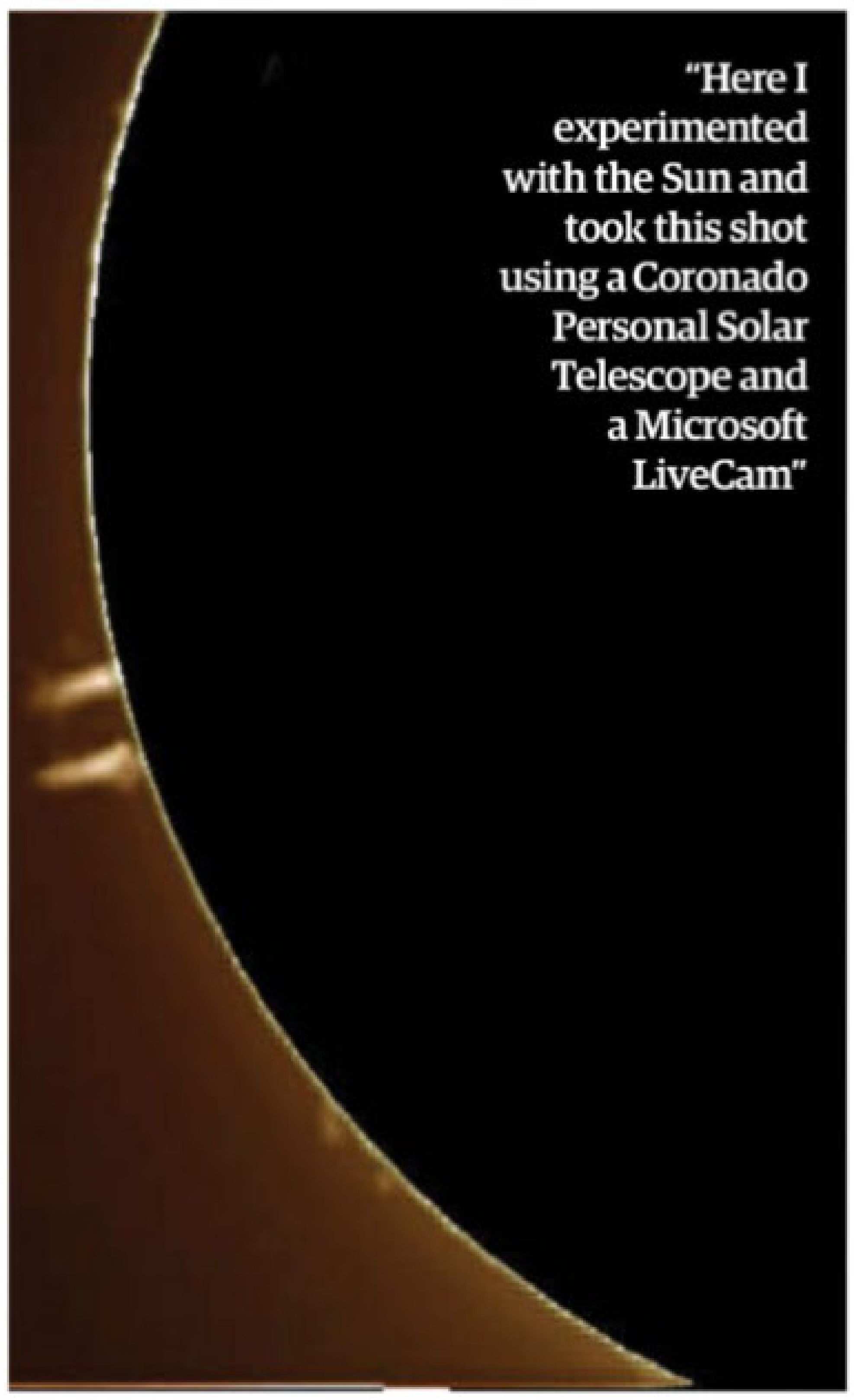
"I tend to stargaze from my light-polluted back garden, however I can still view the planets, the Moon, the Sun and do my spectroscopy from there. Recently I decided to specialise in spectroscopy, which is a challenging field to be in, but I find it truly fascinating given the fact you can learn not only what a star is made of, but how far away it is from its spectra.

"My hobby has taken me to some interesting places where I have met people who have helped both enrich my hobby and my life. For me the interesting part of being an astronomer is when I have documented my skills and created a learning academy (you can visit it at **www.onlineastronomycourses.co.uk**), which also offers GCSE astronomy. I couldn't mention that without adding that my interest has helped give me with another great job as a presenter at Northampton Planetarium.

"I met Sir Patrick Moore at the tail-end of 2012, where I had an opportunity to show him all the letters he wrote to me that inspired me as a child. Sadly Sir Patrick Moore is no longer with us, but the interest and inspiration he passed to me lives on and through that, I pass it to others." ●

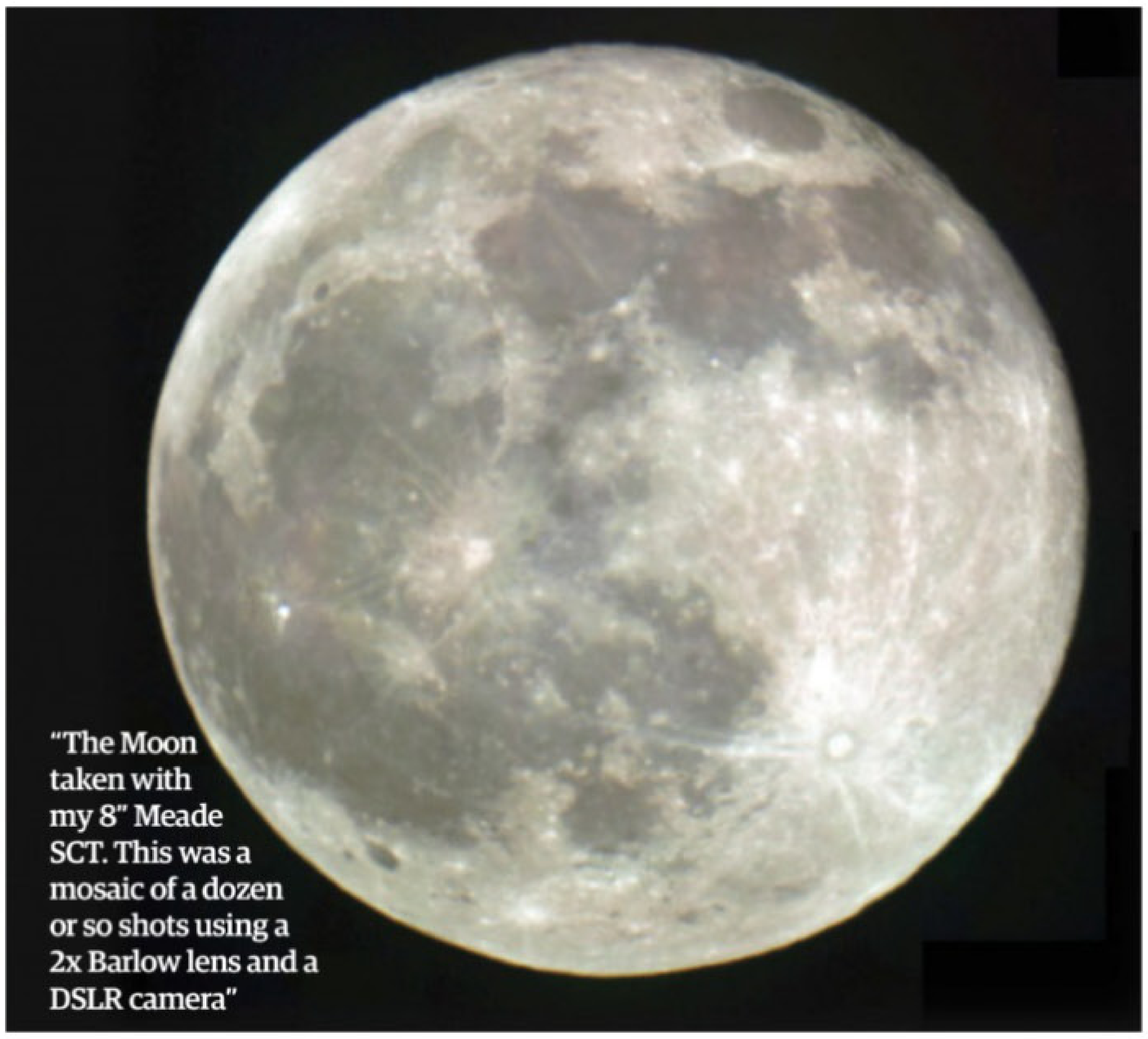
"You can learn not only what a star is made of, but how far away it is from its spectra"

"First image of the Moon taken by my four-year-old son"



"Here I experimented with the Sun and took this shot using a Coronado Personal Solar Telescope and a Microsoft LiveCam"

Alastair with the late Sir Patrick Moore at an astro event



"The Moon taken with my 8" Meade SCT. This was a mosaic of a dozen or so shots using a 2x Barlow lens and a DSLR camera"

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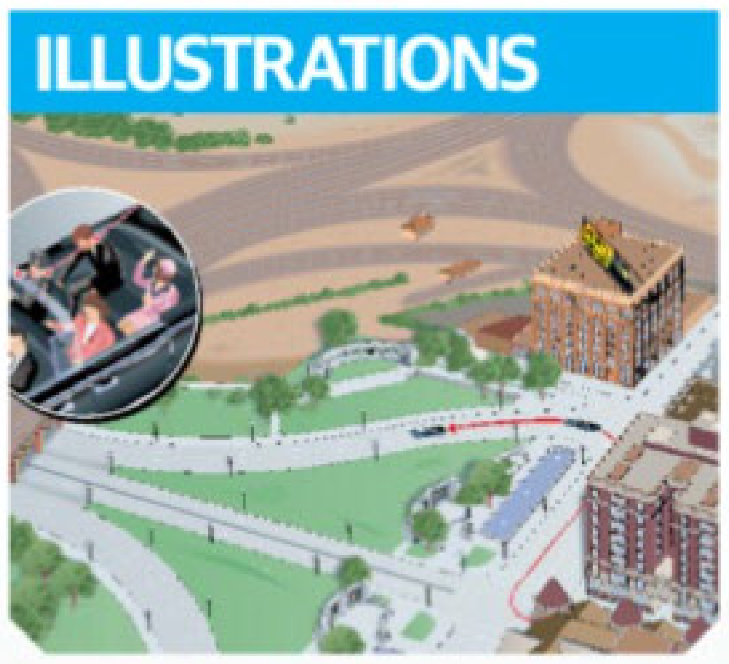

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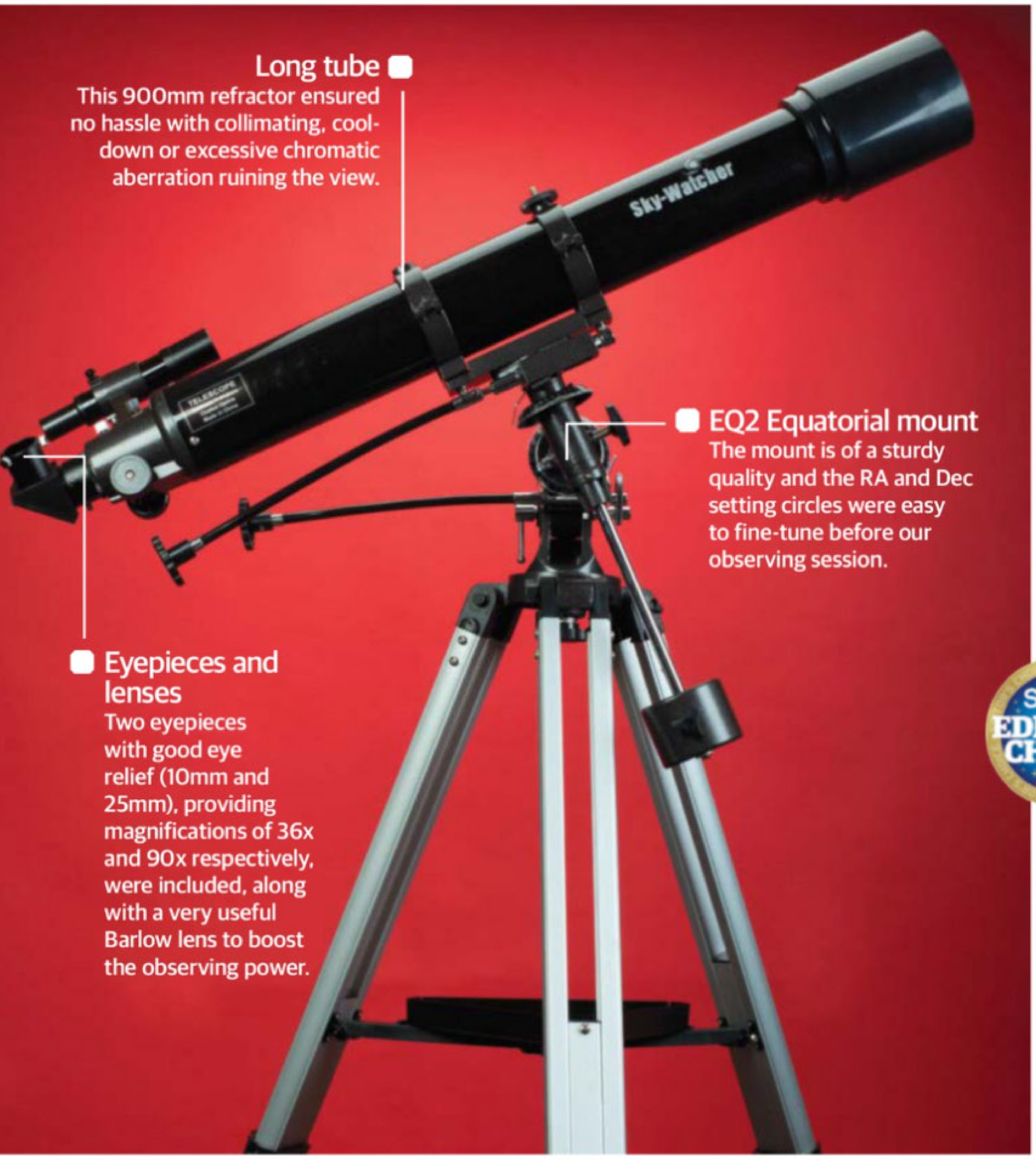
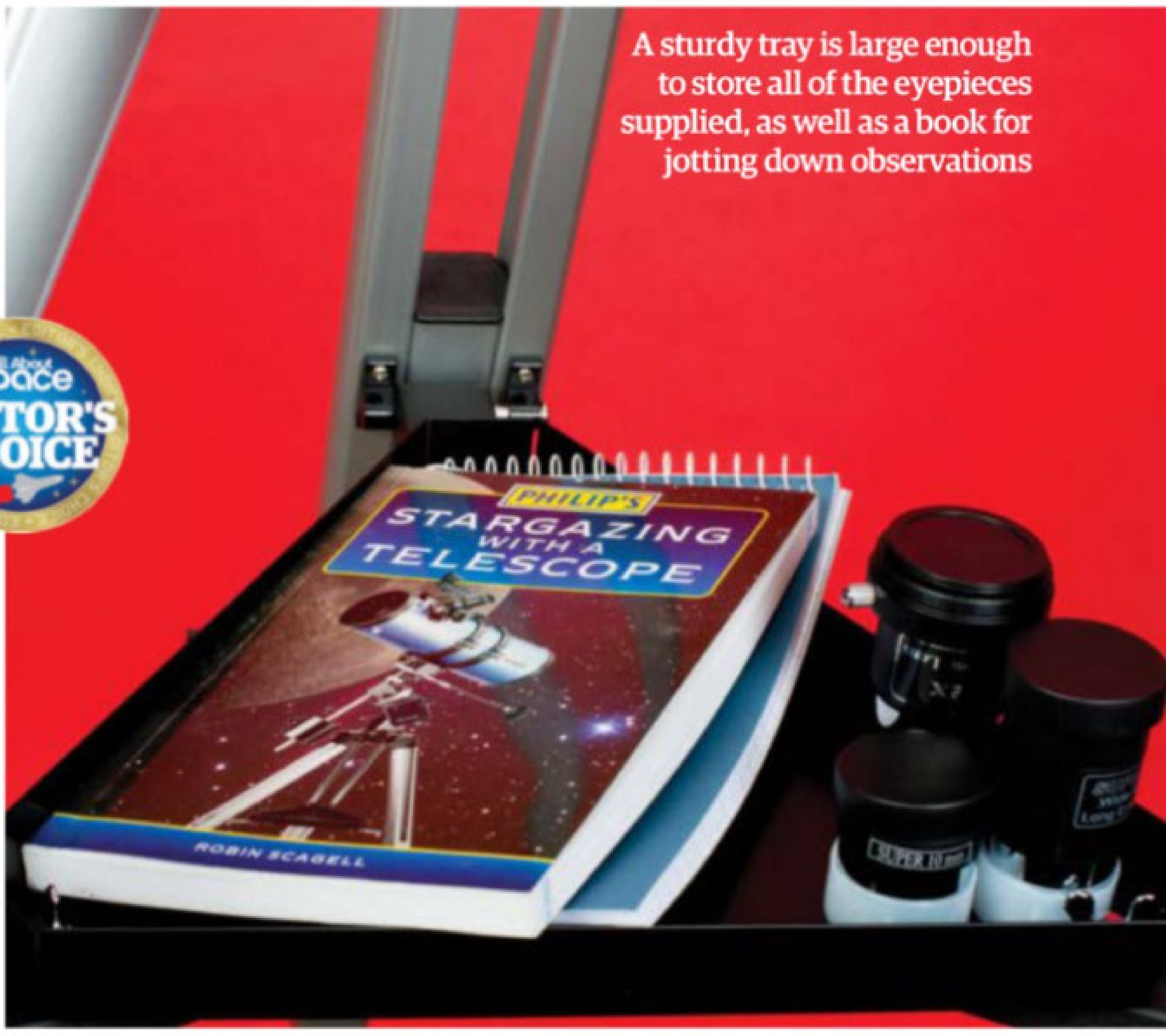
Sky-Watcher Evostar 90

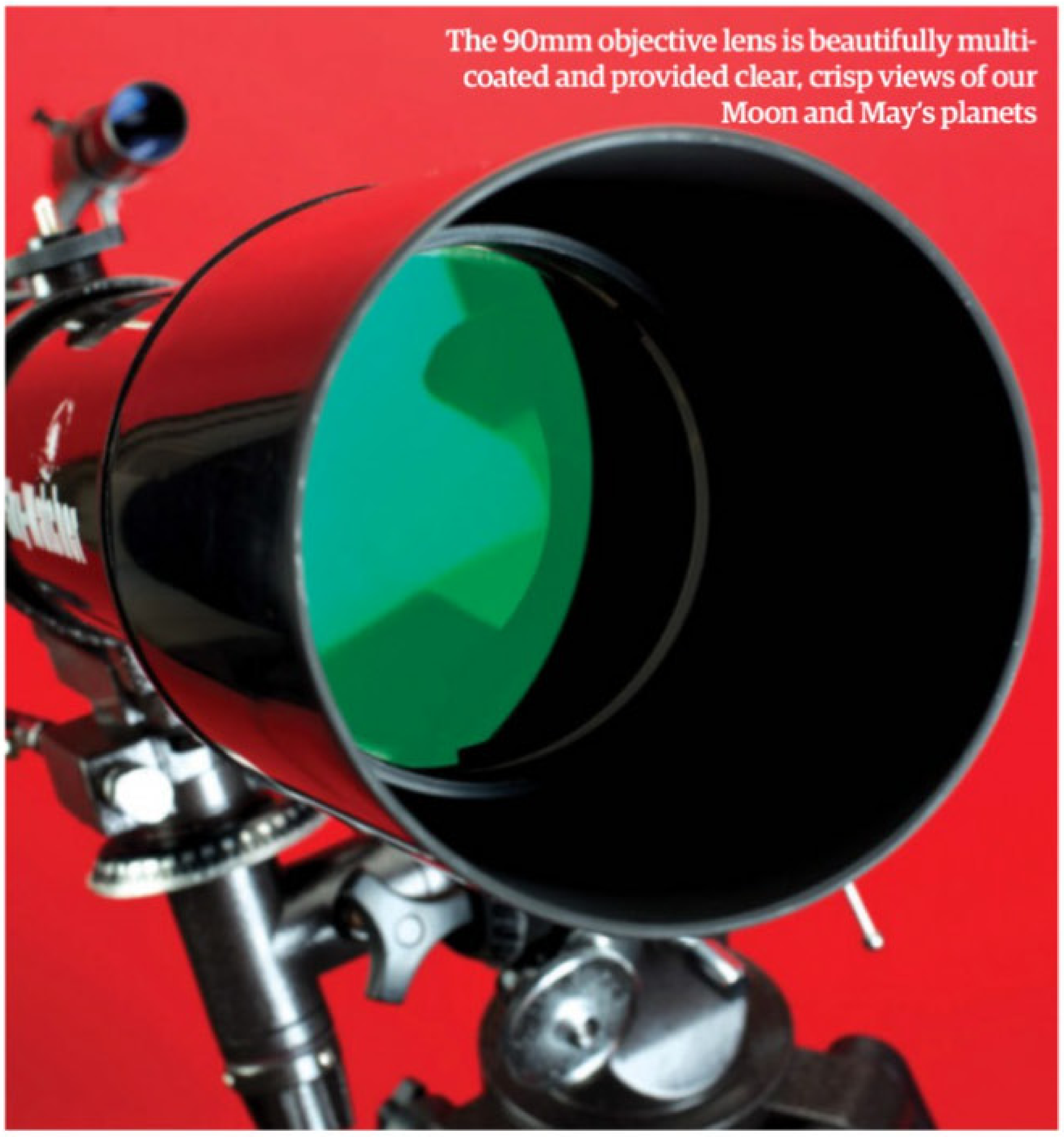
You get more than what you pay for with this excellent achromatic refractor device


Long tube
This 900mm refractor ensured no hassle with collimating, cool-down or excessive chromatic aberration ruining the view.

EQ2 Equatorial mount
The mount is of a sturdy quality and the RA and Dec setting circles were easy to fine-tune before our observing session.

Eyepieces and lenses
Two eyepieces with good eye relief (10mm and 25mm), providing magnifications of 36x and 90x respectively, were included, along with a very useful Barlow lens to boost the observing power.


A sturdy tray is large enough to store all of the eyepieces supplied, as well as a book for jotting down observations


The 90mm objective lens is beautifully multi-coated and provided clear, crisp views of our Moon and May's planets

Telescope advice

Cost: £169 (approximately $287)
From: www.widescreen-centre.co.uk
Type: Refractor
Aperture: 90mm
Focal length: 900mm

At such a low price, you would only expect the bare minimum for this telescope. However, after using the Sky-Watcher Evostar 90, we found that this refractor is more than able to assist with lunar and planetary astrophotography. Also, with a little care and an additional solar film (not included), it can also be used as a basic solar telescope. This is on top of the general lunar and planetary observations you can make with it.

We were delighted to see that you truly get your money's worth (and more!) with this scope. Not only does it exceed the capabilities of other instruments in roughly the same price range, but it also comes with two eyepieces (10mm and 25mm) that boost the telescope's magnification up to 36x and 90x respectively. It's also complemented by a useful Barlow lens, along with a 1.25" star diagonal thrown into the bargain.

The Sky-Watcher Evostar 90 is aimed at beginners, who usually make planets and the Moon their first target, so we're pleased to say the refractor doesn't disappoint. It provided crisp and clear views with no halos or diffraction spikes when turned to bright objects. There was a small amount of chromatic aberration around the Moon, but this didn't affect the observing experience. May's planets were easy to locate and when the 10mm was combined with the supplied Barlow lens, we were able to get good views of Saturn and Mars. ■

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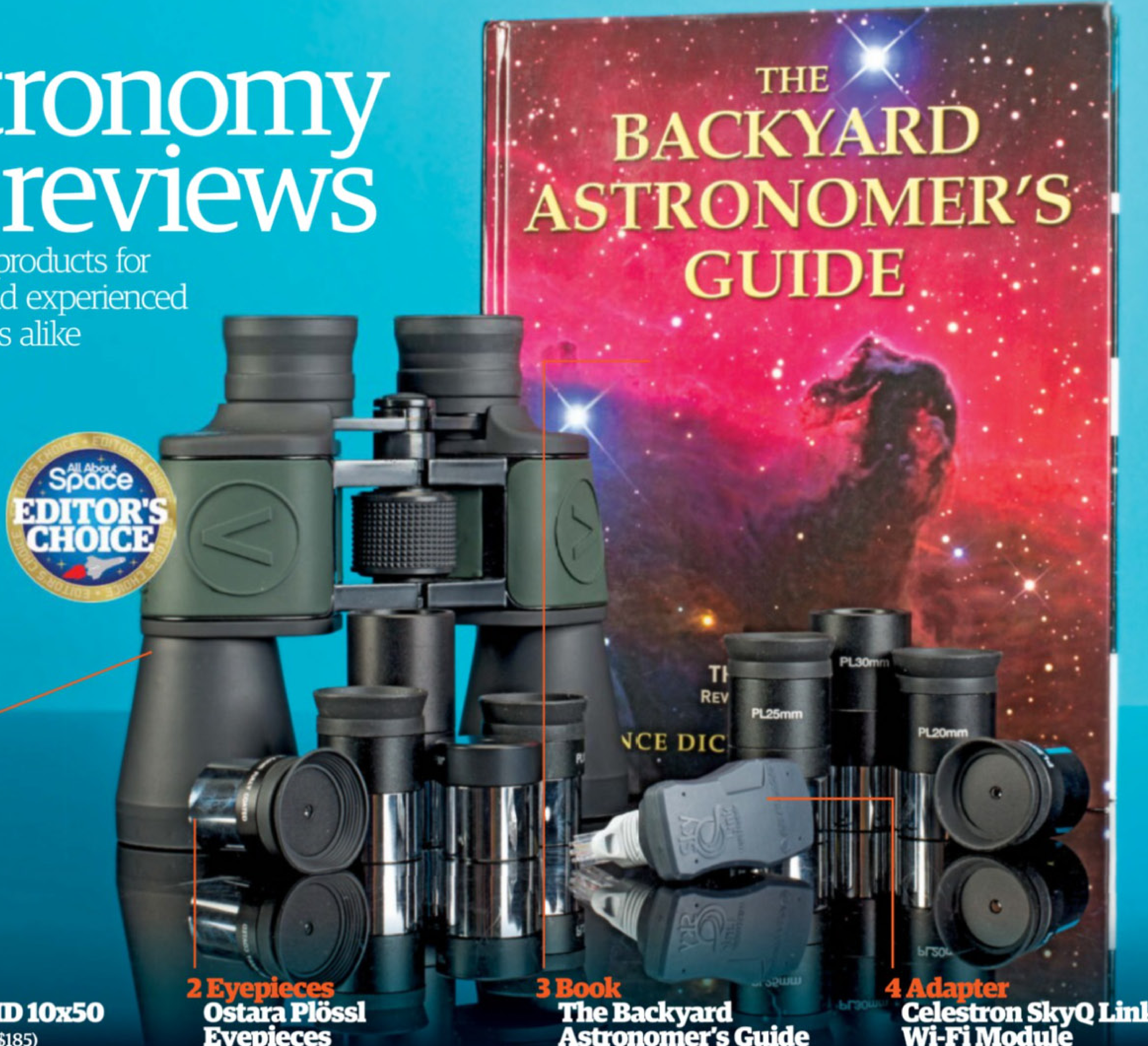

1 Binoculars
Visionary HD 10x50

Cost: £109 (approx. $185)
From: www.opticalhardware.co.uk

An excellent pair of binoculars for the price, the Visionary HD 10x50s are rugged, chunky and easy to hold. Combined with the comfortable, fold-down eyecups and neck strap these binoculars are the pinnacle of comfortable observing for a long session under the night sky. We do advise attaching these binoculars to a tripod for steadier views that are less tiring on the arms, however.

With their 10x magnification and 50mm aperture, the optical system of these binoculars has a decent amount of light-gathering power to pick out a few gems. Aberration did creep in at the very edges of the field of view and the focus was prone to drifting from time to time when we took our finger off the focus wheel.

With an ability to operate in low light, we felt that these binoculars were a must for beginners, as well as a useful piece of kit for veteran and intermediate telescope owners. ■

2 Eyepieces
Ostara Plössl Eyepieces

Cost: Up to £45 (approx. $76)
From: www.opticalhardware.co.uk

We managed to test the full set of Ostara 1.25" Plössl eyepieces (at 4mm, 5mm, 6.5mm, 10mm, 15mm, 20mm, 25mm, 30mm and 40mm) that provided us with a wide range of magnifications and fields of view.

At such a low price, we feared a great deal of internal reflection, but to our surprise were treated to a clear and crisp view with no ghosting when combined with even the lowest-spec telescopes. The 40mm provided superb views of mountains, valleys and craters of the Moon.

The same eyepiece revealed only the two main cloud belts of Jupiter, along with its four main moons as points of light dotted around the gas giant. We did find these eyepieces slightly uncomfortable to use due to a lack of eye cup and it took time to find a suitable resting spot. However, the long eye relief meant that we didn't have to shut one eye. ■

3 Book
The Backyard Astronomer's Guide (Third Edition)

Cost: £30 / $49.95
From: www.fireflybooks.com

With so many guides to the night sky, as well as getting started in astrophotography, it can be difficult to figure out which guide is best for you. This hefty tome is packed with such a great deal of advice, complemented with diagrams and coloured images, we felt that every astronomer should own a copy.

Written by astronomers Terence Dickinson and Alan Dyer, *The Backyard Astronomer's Guide* is comprehensive and every question you might have about making the most of your observing sessions is covered. The authors have even ensured that advice and information has been kept up to date beyond the book itself. Complementing this third edition, the authors have launched the site **www.backyardastronomy.com**, where their outstanding authority on the subject continues. ■

4 Adapter
Celestron SkyQ Link Wi-Fi Module

Cost: £130 / $157.95
From: www.365astronomy.com

Plugging the Celestron SkyQ Link adapter into **All About Space**'s Celestron NexStar 5SE, we were impressed to see how easy it was to use this Wi-Fi module, which enabled us to control the telescope with an iPhone and iPad. We were able to leave the telescope outside and instructed to stare at a planet, while we popped in for a cup of tea.

While this adapter might seem expensive, the ease with which it fits to your instrument – as well as its impressive capabilities – really put any niggling doubt of parting with such a large amount of money to bed.

Not only that, this device seems to answer the prayers of novice astronomers struggling to align their telescope, as this Wi-Fi adapter means the job only takes minutes. Though some stargazers may struggle with the SkyQ Link, we found it did exactly what it says on the tin. ■

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The 10x magnification enables these binoculars to double up as an aid for bird-and general nature-watching, ensuring high clarity, power and a well-balanced image.

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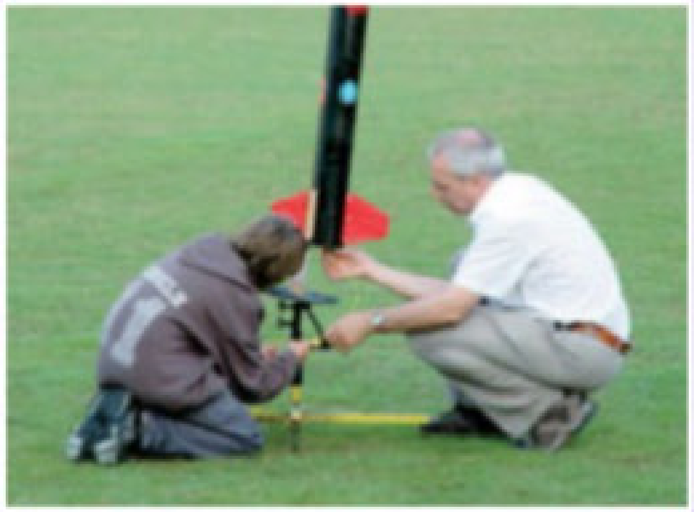

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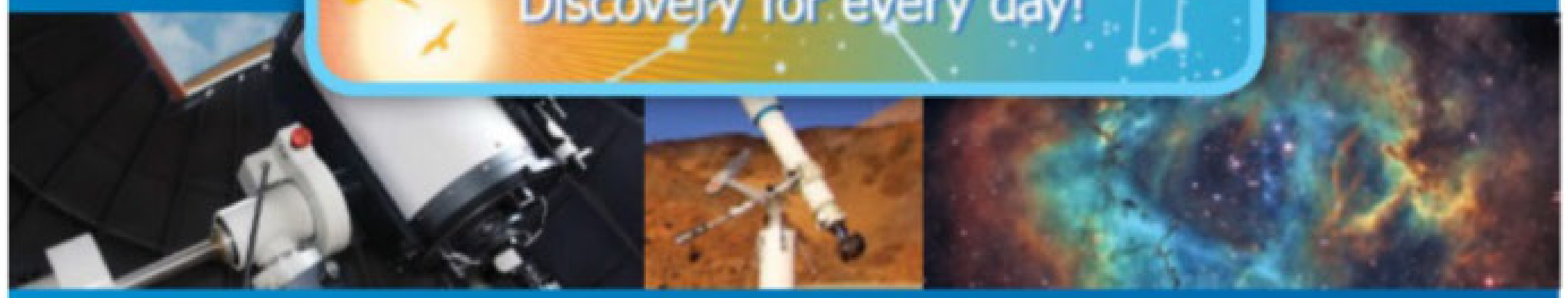

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Sharman responded to a radio advertisement asking for applications to be the first British astronaut, before she was selected on 25 November 1989 to travel into space

Helen Sharman

Britain's first astronaut and first woman to visit the Mir space station

It was 18 May 1991 that saw the first Briton blast off into space on a Soyuz TM-12 rocket. Helen Sharman pipped 13,000 other applicants to the post when she responded to a radio advert that asked for applicants to earn the title of the first British astronaut aboard Project Juno – a co-operative between a group of British companies and the Soviet Union.

However, Sharman didn't grow up dreaming of going to space. Born in Grenoside in Sheffield on 30 May 1963, she went on to gain a degree in Chemistry at her hometown's university before moving to London to earn a PhD from Birkbeck, University of London. After her studies, Sharman found herself employed as an engineer before her passion for chocolate saw her working as a chemist for Mars Inc.

Before she earned her space wings, Sharman had to undergo a rigorous selection process that involved exhaustive physical and psychological exams, as well as testing her ability to learn a foreign language. Some speculated that she was merely selected by lottery, something that, given the paces she was put through for 18 months at Star City, is completely untrue.

Sharman's gruelling flight training was almost in vain. Project Juno was nearly cancelled as schemes that the mission's funding relied on failed to raise enough money to support the project. Unwilling to allow the venture that would carry the fifth youngest individual into space to come to a premature end, the Soviets provided the necessary funds after President Mikhail Gorbachev allegedly ordered for the project to go ahead.

The British Project Juno space program consisted of a Soyuz TM-12 mission, which would also carry Sharman's fellow cosmonauts Anatoly Artsebarsky and Sergei Krikalev up to the space station.

Leaving Earth for just over a week, Sharman spent most of her time in space aboard the Mir Space Station, becoming the first woman to visit the craft. Mir was in orbit from 1986 through to 2001, serving as a micro-gravity research laboratory where crews conducted all manner of experiments in biology, including human biology, physics, astronomy, meteorology and more. Aboard the low-Earth-orbit platform the young astronaut was tasked with conducting various medical and agricultural tests. But it wasn't all work for Sharman, who also got the chance to take shots of the British Isles from orbit and phoned home as she took part in an amateur radio hookup with British school children.

Sadly Sharman never returned to space, however, she was one of three British candidates short-listed for the 1992 European Space Agency's astronaut-selection process. Narrowly missing being selected, Sharman went on to follow a rewarding career as a broadcaster and lecturer specialising in science education. She also joined the National Physical Laboratory as a group leader.

Despite her short time in space, Sharman's accomplishments have not been forgotten. She received a star on the Sheffield Walk of Fame alongside television presenters, politicians, footballers and singers and in 1991 was chosen to light the flame at the 1991 Summer Universiade – or the World Student Games – held in her hometown. On live international television, the opening ceremony unintentionally attracted media attention as Sharman tripped and dropped the games' torch, sending burning embers onto the track as she ran through the infield of the Don Valley Stadium. Not put off, Sharman completed her run around the track before climbing to light the ceremonial flame, which still ignited despite the lack of fire from her torch.

Her efforts were rewarded as she was made an Officer of the Order of the British Empire (OBE) in 1992. In the following year, she also became an honorary Fellow of the Royal Society of Chemistry.

Being such an influential individual, Sharman has had numerous schools in England, as well as the Netherlands, named in her honour, inspiring the next generations to come. ■

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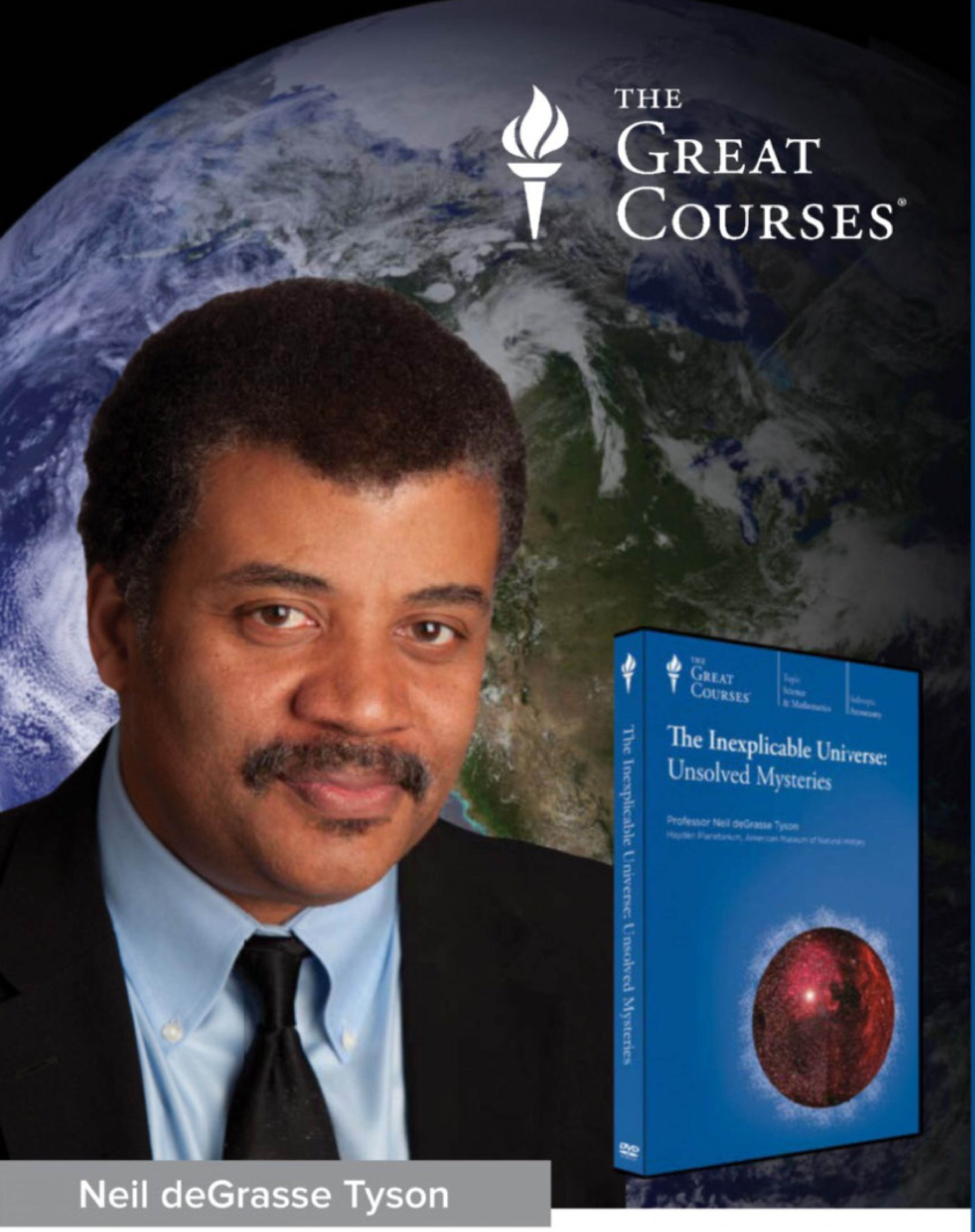
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